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OF

VOLUME XIX, 1903,

PROCEEDINGS.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

PITTSBURG, PA.

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ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The annual meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the society's house, 410 Penn avenue, Pittsburgh, Pa., Thursday evening, January 8, 1903, the President, Mr. Charles F. Scott, being in the chair and forty-eight members and visitors present. The meeting was called to order at 8:20 p. m. by the President. The minutes of the preceding annual meeting were read and approved.

The report of the Board of Directors was read by Secretary C. W. Ridinger as follows:

REPORT OF BOARD OF DIRECTORS.

The Board of Directors recommended the expulsion of the following members for non-payment of dues, the Secretary having made every reasonable effort to collect the dues, and having notified the members of the intended action of the Society: Daniel Boden, Frank I. Cooper, E. W. Cunningham, Leven J. Gray, W. H. Kemler, J. S. Mack, H. B. Miller, Henry F. Miller, John McDonough.

After some discussion as to the dropping of delinquent members, on motion of Mr. J. M. Camp, the recommendation of the Board was approved.

REPORT OF THE HOUSE COMMITTEE.

Mr. Chas. F. Scott,
President,

The House Committee of your Society beg to report as follows:

Your Committee has endeavored to follow out your instructions as contained in letter of August 20th and your recommendations at meeting held earlier in the year.

The furnishment of the house has been reported in Chair-

man's report of September 20th, 1902. Since this report an additional improvement of a heater under the lecture room for heating the lecture room has been placed. The expense incurred by this particular item will be $130.00, with an additional extra for running the gas pipes to the furnace, which was not included in the original bid.

Had your Committee been able to obtain possession of the front rooms on the lower floor and the one room in the third floor front, as was anticipated, all the improvements outlined early in the year would have been accomplished.

No doubt the work of the House Committee has been appreciated by the Society, and its quarters are very much more attractive than they were during the year past.

Respectfully submitted,

E. S. McCLELLAND,

January 7, 1902. *Chairman House Committee.*

REPORT OF RECEPTION COMMITTEE.

MR. CHAS. F. SCOTT,
President,

DEAR SIR—In reply to your request for a report from the Reception Committee, we would say that during the past year informal dinners have been held at the University Club on the evenings of the regular meetings, attended by from 25 to 75 members.

These dinners have proved very pleasant and of real use in enabling the members to become better acquainted. Should the attendance in future prove larger, as is desirable, the University Club's facilities will not suffice and arrangements should be made to hold them at some hotel or restaurant.

During the meeting of the American Society for the Advancement of Science our Society tendered a moonlight river excursion, with refreshments and music, to the visitors. The excursion passed off well, with a large attendance, and all had a good time.

An informal reception and lunch were given to Prof. Sauver in our own rooms.

An excursion, in special trolley cars, was made to the Homestead Steel Works to examine the modern mechanical equipment. Some 125 members and guests attended and a very pleasant and profitable evening resulted.

This fall, on invitation of the Westinghouse Electric & Manufacturing Co., a visit was made to examine the plant in operation and especially to the large generators in course of manufacture and the modern method of matching the parts by use of large portable tools. The method of transit measurement of the work was especially noteworthy. After the inspection of the shops the company tendered a banquet to our Society in their private dining rooms. The occasion was fully enjoyed by all.

It is the opinion of your committee that such visits are very desirable, in that ordinarily our members do not have opportunity to see the work carried on in our midst by our neighbors, and much is to be learned from intelligent observation of other people's methods.

Such trips serve also to bring our members in closer touch and generally tend to promote the welfare of our Society.

The annual banquet, managed so ably by the committee of last year, has already been spoken of in the past. Preparations for our next banquet are under way.

Respectfully submitted,

CHESTER B. ALBREE,

Jan. 2, 1903. *Chairman Reception Committee.*

REPORT OF THE LIBRARY COMMITTEE.

Mr. Chas. F. Scott,
President,

DEAR SIR:—In reply to your letter of December 23rd asking for report of Library Committee during the last Society year, I beg to submit the following:

During the first of the year, in order that the House Committee might make the changes contemplated, it was necessary to move a large part of the library. The Library Committee wrote a letter to the Society under date of March 15th, suggesting that the library was incomplete and very little used, and that

the great bulk of it be given in trust to some other library until such time as our Society saw fit to reclaim it. As the Society at this time recommended that we proceed on these lines, we took the matter up with the Allegheny Carnegie Library and the Carnegie Library, and went so far as to have a card list of the present books owned by the Society made. However, after the Allegheny Carnegie Library and the Carnegie Library learned what books we wished to have them take in trust, approximately half of our books, they both refused to do so, because it was merely duplicating the ones they already had, and they are cramped for room as it is. Owing to these facts, and not wishing to sell, or give the books away, in order to relieve the situation, the books were stored in the cellar underneath the assembly room, where they are now placed awaiting the further action of the Society.

In connection with this it might be stated that at the September meeting of the Society the Society's motion was reversed from its former decision allowing these books to go in trust to some other library on motion of Mr. Thos. H. Johnson. In consulting with him we understand that he merely meant that this applied to the Carnegie Library, and did not oppose giving them in trust to other libraries.

A few suggestions in connection with the disposition of the library in future may be in order. We think that it would be a great incumbrance upon the Society to try to complete the library, or even take care in a proper way of the present library, as it means a librarian to look after the library, its indexing, and issuing of books to the members (at present we have no account or record of any books that are taken out). It seems also as if we would have great difficulty in giving in trust to any other library such periodicals and books as we wish to dispose of, and we would therefore suggest that the books be sold if possible, and if not, given away.

We think this advice is proper, judging from the number of men who have used the Society in the past; two or three only, to the best of our knowledge, having important information to look up have tried to find it in our library during the year. These men can easily get in some much better and more complete form

at the Carnegie Library what they want. A complete engineering library down town perhaps might be of service to a few, but we do not think it worth the trouble and expense to our Society; and furthermore the Carnegie Library expects to establish a down town branch in the near future.

We would suggest then, that we reduce our present library into a few cases of standard and interesting reading matter, which should not be allowed to go out of the Society rooms. These, along with the current periodicals, which could be disposed of as fast as they accumulate either by selling or giving away, the Secretary or care-taker in the library could see to. Having no indexing, he could probably see that the books were not lost, and do what little work was necessary to keep the library in good shape.

Very truly yours,

SUMNER B. ELY,

Dec. 26, 1902. *Chairman Library Committee.*

REPORT OF THE PROGRAMME COMMITTEE.

Mr. Chas. F. Scott,
President,

Complying with the request of the President of the Society, Mr. C. F. Scott, for a report from this Committee, I beg to submit the same as follows:

The Committee entered upon its duties by preparing the programme for the month of March, 1902, and presented during the year the following subjects and papers:

March—Automobiles, 1 paper.

April—The Electric Motor in Industrial Establishments, 6 papers.

May—Modern Office Buildings, 4 papers.

June—The new Union Station, P. R. R., Pittsburg, Pa., 4 papers.

September—New Fort Wayne Bridges. Elevated Tracks at Pittsburg, Pa. Our River Commerce, 4 papers.

October—Briquetting of Flue Dust and Fine Ores. History of Our Local Bridges. Some Interesting Notes Relating to Early Railway Operations, 2 papers.

November—The Use of the Microscope in the Determination of the Properties of Steel, 1 paper.

December—Reminiscences, 6 papers.

January—Pittsburg's Transportation Problems, 4 papers.

This makes a total of thirty-two papers for the nine regular meetings, in addition to which two papers appear in our proceedings for the month of August, one a report by Mr. C. B. Albree, who represented the Society at the Glasgow Engineering Congress in September, 1901, and presented at a special meeting, held Tuesday evening, April 2, 1903. The other a description of "The Arcophone, or Speaking Arc Lamp," exhibited by Messrs. Snyder and Smith at the same meeting.

Another very interesting (special) meeting was held on April 29th, when the Metric System was discussed, and it is to be regretted that a stenographic report of that meeting could no be made for publishing in our proceedings.

Your Committee was also instrumental in bringing to Pittsburg Mr. E. L. Corthell, of New York, who lectures under the joint auspices of the Engineers' Society and of the Academy of Science and Art, on Saturday evening, Jan. 3, 1903, on "Argentina, Past, Present and Future." To properly present this lecture we were compelled to enter into negotiations with the Academy in order that we might have a hall suitable for the occasion, as we feared the capacity of our own rooms would be greatly overtaxed as they were when Prof. Albert Sauveur lectured for us in November.

Throughout the year it has been the policy of the Committee to determine the subject for each meeting and to procure papers on the subject, rather to ask for papers promiscuously, regardless of what the subject might be. The success of the year can be attributed very largely to this method, and on at least one occasion, where we found we did not get sufficient response to make a creditable showing, we laid aside the material we had gathered, took up another subject, and, with very little time for preparation, presented one of the best programmes of our series.

Without any explanation, (or excuse for our own members), I will state that nearly one-half of the papers presented during the year were read by non-members of the Society.

Considerable assistance has been rendered by the various members in suggesting the names of persons who have read papers for us, and while acknowledging the service thus rendered, we wish to publicly express our appreciation of the aid given us by Mr. Frederick C. Schatz, of the House Committee, and his assistants, Messrs. Harry Tiernan and Wm. Blevens, for arranging apparatus on the occasion of the November meeting.

In the above remarks I have given a brief review of what has proven to be probably the most elaborate programme presented during any one year of the Society's existence, and which your Committee believes has been a very large factor in bringing about the greatly increased attendance at our meetings, and in promoting the general welfare of the Society. Your Committee earnestly hopes that the present year will not be known in the Society's history as a banner year, but that it will merely mark the beginning of a new epoch in the scope and usefulness of the Society.

Very respectfully submitted,

RICHARD HIRSCH,

Chairman Programme Committee.

Jan. 2, 1903.

METRIC SYSTEM MEETING.

On April 29th the Society held an extra session for the discussion of a bill before Congress, relating to the adoption of the Metric System.

President Scott opened the meeting with some well chosen remarks and then called for a report from the special committee appointed at a previous meeting to collect data from the members.

Prof. Kintner, chairman of the committee, reported a canvas of the Society by circular letter and offered the following resolutions as embodying the sentiment of the majority of the replies:

Resolutions suggested by the Special Committee appointed to report on the Metric System and the feasibility of its adoption:

WHEREAS, An international Standard of Weights and Measures is desirable; and

WHEREAS, The present system of Weights and Measures in use in this country is extremely complex in its interrelations, unsuited to future engineering and commercial development, and one for which there can be no hope of international adoption; and

WHEREAS, The Metric System, as developed by the International Bureau of Weights and Measures, is the best system of weights and measurer known, exceedingly simple in its interrelations, greatly simplifying the work of enumeration and computation, and well adapted to all engineering and commercial work; and

WHEREAS, The Metric System has been adopted by all except two of the civilized nations of the world.

Therefore be it resolved, That the Engineers' Society of Western Pennsylvania approves of any movement which will help to bring about a universal adoption of the Metric System with reasonable economy of transition.

And be it further resolved, That the United States Congress should enact such laws as will lead to the early adoption of the Metric System as the Standard of Weights and Measures in the various departments of the National Government.

A very interesting discussion followed, participated in by the following members and visitors: Messrs. Bole, Albree, Knowles, Stahl, Ely, Engstrom, Mattice, Tyler, Scott and Wadsworth.

The resolutions were adopted as read and the meeting adjourned.

S. M. KINTNER, *Chairman.*

The Treasurer's report was read by Mr. A. E. Frost as follows:

REPORT OF TREASURER FOR YEAR ENDING JANUARY 8th, 1903.

EXPENDITURES.

Salary of Secretary	$ 600 00	
Rent of Society House	1,560 00	
Office Expenses	300 48	
Printing	2,120 25	
Stenographer	80 00	
Illustrations in Proceedings	96 95	
Repairs and Improvements	916 72	
Periodicals	18 50	
Heat and Light	257 07	
Insurance	119 80	
Typewriter and Desk	108 50	
Telephone	37 30	
Transferred to Lunch Fund	15 00	
Button Badges	18 75	
Total		$6,249 32
Balance, Jan. 8th, 1903		364 27
		$6,613 59

RECEIPTS.

Balance, Jan. 21, 1902				$1,125 38
Dues, to Jan., 1901, at	$7 00	4	$ 28 00	
" " " " "	5 00	8	40 00	
" " " 1902, "	7 00	22	154 00	
" " " " "	7 00	1 ½ year	3 50	
" " " " "	7 00	1 ¼ year	1 75	
" " " 1903, "	5 00	62	310 00	
" " " " "	5 00	3 ¾ year	11 25	
" " " " "	5 00	3 ½ year	7 50	
" " " " "	5 00	6 ¼ year	7 50	
" " " " "	7 00	320	2,240 00	
" " " " "	7 00	60 ¾ year	315 00	
" " " " "	7 00	15 ½ year	52 50	
" " " " "	7 00	24 ¼ year	42 00	
Initiation Fees,		139	695 00	
Rents			850 00	

Sale of Proceedings	687 71	
Contribution to Library	6 00	
Buttons	8 00	
Reception Committee	15 00	
Binding	1 50	
Dues, to Jan., 1904, at $7 00 1	7 00	
" " " " " 5 00 1	5 00	5,488 21
		$6,613 59
Balance in Key Deposit Fund		$ 25 00
Balance in Lunch Fund		14 74
Balance in Building Fund, Jan., 1902		1,144 07
Cash Donation during year		25 00
Interest		45 70
Balance on hand January 3, 1903		$1,189 77

The report of the committee appointed to audit the accounts of the Treasurer was then read by Mr. H. J. Lewis as follows:

AUDITOR'S REPORT.

We, the auditors appointed to audit the accounts of Mr. A. B. Frost, Treasurer of the Engineers' Society of Western Pennsylvania, beg to state that they have performed that duty and find the same correct in every particular.

H. J. Lewis, *Chairman*,.
Geo. T. Barnsley,
Selwyn M. Taylor.

The report of the Secretary was then read by Mr. C. W. Ridinger as follows:

REPORT OF SECRETARY FOR YEAR ENDING JANUARY 8, 1903.

Members at close of year ending Jan. 21, 1902		470
At the Annual Meeting, Jan. 21, 1902, there were six (6) names dropped from the roll	6	
There were fourteen (14) resignations and two (2) deaths during the year; a total	16	
A total loss of		22

During the year two (2) of the applicants elected in 1901 matriculated	2	
During the year one hundred and fifty-nine (159) applicants were elected members, and of these one hundred and thirty-eight (138) matriculated	138	
A total gain of		140
Making a net gain of		118
Total membership, Jan. 8, 1903		588

The average attendance at the regular meetings of the Society during the year was one hundred and seven (107).

Approximate amount of dues and initiation fees unpaid and owing to the Society $625 00

Upon motion these various reports were ordered received and spread upon the minutes.

Upon motion the Society took up the next regular order of business, which was the election of officers.

Mr. Hirsch moved that the Secretary cast the ballot for the following named candidates:

Ballot—January 8, 1903.

President—(1 year), Chester B. Albree.

Vice President—(1 year), James M. Camp.

Vice President—(2 years), Samuel Diescher.

Directors—(2 years), Samuel M. Kintner, Selwyn M. Taylor.

Treasurer—(1 year), A. E. Frost.

Secretary—(1 year), C. W. Ridinger.

This motion was unanimously carried and the Secretary cast the ballot and the candidates were duly elected.

The retiring President, Mr. Charles F. Scott, then delivered his address.

"THE ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA."

ADDRESS OF THE RETIRING PRESIDENT, CHARLES F. SCOTT.

I have chosen for the address which marks the completion of my term of office as President a theme in which I have been greatly interested and to which I have given much thoughtful consideration during the year. The title is familiar to you—it is, The Engineers' Society of Western Pennsylvania.

At the opening of the year, at our annual banquet, I took occasion to direct your attention to some of the unique opportunities and possibilities which are possessed by a Society such as ours, located as we are. I appealed to the members, each to "do his share, large or small, with earnestness and enthusiasm to promote the dignity and success of the Society."

There has been marked activity along several of the lines of development which were indicated at the beginning of the year. But before relating what has been done I want to say in how large a measure the results have been due to the ready co-operation of the officers of the Society and to the interest taken by its members. It has been my lot to have been chosen the leader, the general. A general may indicate what ought to be done, but whether it is achieved or not is determined by the efficiency of his staff and the spirit of the men in the ranks. Especially to be commended are the persistent efforts which have changed the old-time paucity of papers into an almost superfluity, the repeated plannings which have lead to so many social events and the vigor which so completely transformed the appearance of our Society rooms in a single month.

At the beginning of the year it was determined not Micawber-like to wait for something to turn up, but rather, on the principle that to him that hath shall be given, to use well the facilities we have and thus to demonstrate what possibilities there may be for further development.

It will be well worth our while to review briefly the work

which has been done in order to note particularly what future possibilities are indicated by the increased activities of the past year.

THE WORK OF THE PAST YEAR.

The Committee on Papers began its work with a provisional programme. Nearly all of our meetings have been in subsbtantial accord with the preliminary plan. In most cases several short papers dealing with different phases of a common subject have been secured for presentation on the same evening. In general the subjects were related to live engineering matters of local intrest and importance. The meetings arranged by the present committee are as follows:

March, Automobiles, 1 paper.

April, The Electric Motor in Industrial Establishments, 6 papers.

May, The Construction of High Office Buildings, 4 papers.

June, The New Union Station, Pittsburg, 4 papers.

September, Allegheny Track Elevation; the Double-Decked Bridge; Transportation Possibilities of Pittsburg's Rivers, 4 papers.

October, Briquetting; Old-Time Acqueducts and Bridges Across the Allegheny, 2 papers.

November, The Microscope in Its Relation to Iron and Steel Determinations, 1 paper.

December, An Evening of Engineering Reminiscences and Achievements, by three past presidents, the coming president, an old-time member and a distinguished naval guest, 6 papers.

January, Pittsburg's Transportation Problems, for which 4 papers are expected.

As a rule the 32 papers have been written by experts, frequently by men who are eminent in their respective lines, and the discussions have been excellent.

It is usually easier to obtain short papers from several busy men than it is to get a single long paper from one of them.

At an extra meeting last Spring the expediency of the adoption of the metric system was ably discussed, pro. and con. The

report of the meeting would have added to the value of our proceedings had the discussion not been so animated and technical that it overtaxed the ability of a new stenographer. On account of the limited capacity of our assembly hall for the lecture last week of Mr. E. L. Corthell, well known to many Pittsburg engineers, and recently special engineer to the government of Argentina, arrangements were made for a joint meeting with the Academy of Science and Art in the Carnegie lecture hall.

The record-breaking banquet of nearly 300 which ushered in the year gave inspiration to the new Reception Committee. The invitation to an informal reception and dinner just before the regular meetings has met with a hearty response. Members and their friends have enjoyed the hospitality and excellent service of the University Club on seven such occasions. Older members who had not attended a meeting for years have appeared, presumably to see what was going on, new members have come in freely, those who were to read papers were usually there and all have had an opportunity to meet one another and the officers. At a special meeting in the spring the Society's delegate to the International Engineering Congress at Glasgow made an interesting report, which was followed by refreshments. About 135 joined the excursion to Homestead in April, and about twice as many accepted the invitation to the Westinghouse Electric & Manufacturing Company to visit its works at East Pittsburg in November.

Our members were active on various local committees in connection with the Pittsburg meeting of the American Association for the Advancement of Science in July and the Society tendered an evening river excursion to the visiting scientists.

Probably nothing has been effected which is more striking than the transformation of our assembly hall. The old-time book cases along the walls with a cornice of dusty overflow—for part of what would not go inside was on top—and the pile of papers in the corner are no longer in evidence, and even the folding chairs are gone. Linoleum, wall paper, paint, new lights and new furniture complete the transformation of the hall, whose comfortable seating capacity has been increased by one-third. A new coat room and the papering and painting in hallways and office rooms as well as our name on the entrance transom all testify to

the successful labors of the House Committee. There is disappointment that more could not have been done. It was not found practicable to fit up the parlors on the first floor for a reading and reception room during the past summer as was planned. The rooms will be available April 1.

The library is not in a satisfactory condition. Valuable in some departments, sadly lacking in others, it is not adequate for general reference, it has not had convenient and sufficient space, it has not been heated in winter, it has had no catalogue, it has had no attendant, it has had but few visitors, and some who have tried to use it have had their labor in vain. The cases, inadequate even for the books we have, encroached upon the needed space of our assembly hall. The suggestion that we retain a good reading room equipment and deposit our reference books with another library which would index and care for our books and make them much more available to our own members, as well as building up a great reference library, met with the unanimous approval of the Library Committee, the Directors and the Society itself at a meeting early in the year. Negotiations with the Carnegie Library were not concluded when we were ready to refit the assembly room. The library was therefore stored in a room on the ground floor. The Society has recently adopted a resolution instructing the Directors not to carry out the proposed plans. No adequate suggestion has been made as to the disposition of the library in our present society house. The Carnegie Library is ready to cooperate with a view to receiving our books and making them accessible, the ownership to remain with us. That library is proposing to expend money and duplicate some of our books, whereas if our books were there these funds could be spent for other additions to the greater general good of our members.

The usually thankless task of getting by-laws prepared and adopted was completed at the May meeting. The material which had been prepared with great care several years ago had been vanquished in some contest over its provisions and had rested undisturbed until it was reviewed by its originators and the Board of Directors and then adopted by the Society. It was printed with the membership list in convenient pocket book.

MEMBERSHIP AND ATTENDANCE.

The committees of the Society have been active. Have their efforts been successful? What has been the response? Increase in membership and attendance are a fair measure of the general interest. The number of applicants elected to membership since the last annual meeting is 159, which is more than one-third of the number of members a year ago. The net gain in membership (a few have not yet matriculated and some have withdrawn) is 118, an increase from 470 to 588, equal to 25%. The net gain from 1894 to 1901, 7 years, was 7%. The average attendance at the regular meetings under our present committees has been 107, the maximum was 170 and the minimum 64. During the preceding four years the average attendance ranged from 37 to 48, with a mean for the four years of 42. Only once during these four years did the attendance exceed the average of the past year and on only four occasions in four years did it exceed the minimum of 64 above mentioned. At the informal dinners preceding our recent meetings the attendance has ranged from about 25 to 75 and has had a mean of 40 to 45 equal to the average attendance at meetings during several preceding years, while the average attendance of 107 at the recent meetings is $2\frac{1}{2}$ times that of the four preceding years. This takes no account of two special meetings and several excursions, nor the attendance at the monthly meetings of the Chemical Section. The number of pages in our proceedings has increased over 80%.

WHAT SHOULD THE SOCIETY BE?

What does this review of the past year augur for the future? Does it not indicate clearly that the engineers of Pittsburg appreciate this Society and that they are ready to respond in measures for increasing is activity? Measured by the preceding years the past year indicates notable progress, but are we approaching our limits? To what extent are we realizing the possibilities of an engineering society in the city of engineering works?

Before answerng these questions we should develop definitely what such a society should be and what it should do. We

should crystalize our ideals, but we are apt to find it harder to state them than we realized before we tried.

I think it is a common idea, and it is one which I used to hold that the function of the Society is to have papers presented and that its ends are accomplished when ten papers are presented at ten meetings annually. The profounder the papers and the more learned the discussion, the better. Although a paper may not be within the range of my own interest and comprehension, I feel of course—whether I attend the meeting or not—that it is doing others good and the proceedings are of great intrinsic value. There is also an annual banquet. The success of the banquet varies directly as the attendance and the number of good stories and inversely as the length of the solemn speeches.

If only 10% or 20% of the members attend the monthly meetings, or an average for each member of once or twice a year, and if all but one or two of the papers during a year are of little interest or value to a given individual, we are paying in our annual dues a high price for the returns we get. Or course, we may count in with our assets the satisfaction in feeling that we are supporting a society which has a dignified record and is theoretically a very good thing.

Now I confess that as ridiculous as this position may seem it describes fairly well my own relations to the Society for several years. The change in my attitude began when I met at a friend's house a now ex-president who talked about the Society and its affairs in a new way. It was not merely a scientific society to be supported for theoretical reasons. He showed a deep personal interest in it. It reminded me of my own enthusiasm for the first college literary society to which I belonged. When later I was honored by a place on the Board of Directors, I found men who had interest, who had enthusiasm, who did work. One little thing impressed me particularly. The President said "our" Society, not *the* Society, but *our* Society—he did it unconsciously, he did it because he felt it.

The men who have gotten the most out of the Society are those who have put the most into it. They are the men who have spent many a Saturday night at a Board Meeting, they are the men who have attended the regular meetings, they are the men

who have gotten acquainted with one another and the thing they value most is that acquaintance. I would not exchange the acquaintance of any one of half a dozen or a dozen men whom I have learned to know for all of the Society's papers that I have heard or read.

WHAT AN ENGINEERS' SOCIETY STANDS FOR.

An Engineers' Society stands for something more than mere technical dissertation. The engineer himself is a narrow and ill-developed man if he confines himself strictly to his own facts and formulas and has no interest in the work of other engineers and no appreciation of that which lies without his own narrow limits and takes no pride in his profession. Just so, a Society must not be confined within too narrow limits. It stands for the engineering profession. It is the means for intercourse between engineers whose lines of work are similar and also between those whose lines of work are diverse. Engineers are specialists, the tendency is to concentrate effort within restricted bounds. Acquaintance, association, intercourse are essential to broaden our knowledge, our vision and our sympathy. Engineers have aims which are common and interestes which are common. By unity they may take measures which will increase their individual efficiency, they may advance the effectiveness and the value of engineering work in general and they may raise the standard and the influence of the engineering profession.

But let us make our ideas clearer by considering more in detail the functions of the engineer and his relations to others. Engineering, according to the unabridged, is "in its modern and extended sense, the art and science by which the mechanical properties of matter are made useful to man in structures and machines." The work of the engineer underlies civilized life, it is the engineer who conquers and controls and adapts and uses the forces and the materials of nature. Take away the steam engine from the nineteenth century, take it from the railroad, the ocean vessel, the factory, the mill and the mine, take away the telegraph and the cable and the telephone, the electric light and the electric motor and consider how differently the history of the progress of

the century would read. It is the work of the engineer which underlies industry and commerce, modern agriculture and mining and makes possible the higher comforts and opportunities of modern life. Our whole modern civilization is a great mechanism, growing more and more complex each year. The engineer has been prime factor in the past—but how much greater are to be his importance and his responsibility in the future! The pace is accelerating. The engineering advancement of the past ten years is greater than that of the ten centuries which preceded Watt. Each advance encounters new problems of greater magnitude and difficulty, which call for a higher order of engineering ability. Witness the experience of the electrical engineer. His work is never done. No sooner are given conditions met than new ones appear. They are fulfilled only to reveal a larger demand. The first electric railways in Pittsburg were supplied with generators of about a hundred horsepower. Sizes have increased step by step until those of the Manhattan Railway Company can readily develop 10,000 horsepower. In the same time pressures have gone up step by step—each increase bringing new problems—until from 1,000 or 2,000 volts, covering a distance of a few miles, pressures of 40,000 volts and 50,000 volts have been made commercial and power is transmitted 100 or 200 miles.

It is fitting that engineers should pause in their work, that they should take a broad view of the present and the future. What is to be done? How is it to be done? How may we equip ourselves for the enlarged responsibilities which confront us?

THE ENGINEERS OF PITTSBURG.

Let us view the situation from a different point of view—less general, more definite and personal. We are engineers of Pittsburg—and by Pittsburg I mean engineering, industrial Pittsburg, the Greater Pittsburg, unlimited by the narrow lines which contribute to but one kind of prosperity—to political prosperity. At our last meeting our distinguished past president, Mr. Metcalf, told us a fascinating story of the days—some 40 years ago—when he came to Pittsburg. There were then in the whole city only two draughting rooms. A few timbers were sufficient foun-

dation for the machinery in the mills. He came here in the year that a railroad bridge was built across the Allegheny—to the disgust of bus-drivers and draymen. How much has the advancement of 40 years in invention, in the development of industrial processes, in the building of furnaces and mills and factories, in the perfecting of the quality of the output as well as superintending its production—how much of what is fundamental to Pittsburg is due to the intelligence, the skill, the experience of her engineers? I read somewhere recently that an English traveler some 50 years ago reported the industrial position of the United States by saying that it had no second Birmingham. I read also the comment that at the present time England has no city which is a worthy second to Pittsburg. If Pittsburg has taken first place in this country, and America is pushing to the front for the industrial supremacy of the world, let it not be overlooked that this is a contest in which there must be a man behind the gun. When Mr. Metcalf came to Pittsburg there were but two draughting rooms. When I came to Pittsburg and knocked at the side door of a factory one of my qualifications which counted against me in the mind of the superintendent was that I "was a college fellow." Now the same firm sends each year to the technical schools asking for their best men.

In the light of the past and in the tendencies of the present what can we discern of the future? We have reached no goal of excellence or of prosperity which others cannot attain, nor have we even the standards which will endure —they will soon be inadequate and obsolete. The industrial awakening and quickened activity of all modern life require continual advancement if we would lead. Better products, cheaper products, increased output are demanded. To meet this demand requires higher intelligence, technical training and skill, and wider experience. It presents larger problems to the engineer, it enlarges the responsibilities which he must assume, responsibilities for particular undertakings and responsibilities for doing his part in the world's work. How much of the material comforts which are found in modern life, how much of the material prosperity of these recent years are due to the engineer,

and how much more must the future depend upon him for their continuation and extension. He has shown how to do the world's work more efficiently. One man can do the work of two—of ten —of an hundred. Recently I visited a Southside mill. I saw many tons of molten steel poured into a great ladle, the ladle was lifted and carried across to empty its contents into the ingot moulds. A few minues later I passed a laborer carrying a 12-foot board. He was working harder than the man who moved the ladle.

In general the men who manage the Pittsburg industries are the men who have been engineers—educated in the school and in the mill. The ability to organize and direct the forces and the materials of nature is a fit training for one who is to organize and direct men. Would that those who direct our government and our finances were engineers who could apply their engineering training and methods to the introduction of wise policy and of efficient methods to secure beneficient results. Would that the same ability and energy which makes Pittsburg's industry successful could be applied to promote the general welfare!

PITTSBURG AND ITS ENGINEERS' SOCIETY.

But we are Pittsburg engineers and we must return to our own problems. We are members of its Engineering Society—what is its field, its possibilities, its mission? What part is it to take in the work of the future? Has it reached its proper limits? Is it doing its normal work, or are its possibilities still latent? We pride ourselves upon being the representative body of the engineers of industrial Pittsburg. We congratulate ourselves that our membership has increased and the attendance at our meetings has more than doubled. But are 600 men an adequate representation of the engineers of Western Pennsylvania? Are there not 600 men eligible to membership in each of several of the large industrial interests which are located here?

There is probably not another local engineering society in the world so favorably situated as ours. Our position is unique, but our membership is meager. We congratulate ourselves that 100 men attend our meetings each month, but what are 100 men meeting

10 times a year! Has there been a meeting during the whole year that would not have been interesting and profitable to a thousand Pittsburg engineers—at least a thousand among the many thousands who are doing engineering work within an hour's radius from the city's center?

We have failed to appreciate the largeness and the consequence of the engineering profession. We have worked as individuals. We have failed to recognize our kindredship and to act together in a common interest. We recognize the tendency toward concentration and the efficiency of working on a large scale in manufacture, in commerce and in organization and financial management. We recogize that it is the engineer who has supplied the fundamental and underlying means by with this coöperation and large working is made possible, but we whose work has been of such fundamental importance in modern development and we who have shown others how to work efficiently have failed to catch the spirit of the times and to apply to our own work the methods which have been so productive of efficiency elsewhere.

AN UTOPIAN SOCIETY.

Let us journey to the utopian Pittsburg of the future and visit its Engineering Society. Walking along a clean and well paved street I am attracted by a familiar title and enter the magnificent home of the Engineers' Society of Western Pennsylvania. There is an air of welcome and comfort in its halls and rooms. There are writing tables and books and papers; there is a general semblance to the rooms of a club, but there is not that air of exclusiveness which indicates that the limitations are those of wealth and privilege. Upon looking about and talking with the attendant I learn that the Society has a large and growing membership, that it includes the men whose work has made Pittsburg what it is, and the men who are the present leaders in engineering and industry, and that it has a large number of young men, men who have left their homes and come to the city enlisting in its engineering service. Others are the young men of Pittsburg working their way up by lessons of experience. The

criterion of eligibility for young men is that they have undertaken engineering work and by their earnest spirit and effort give promise for the future. I learn that the sentiment of the Society is that these young men are those who are to shape Pittsburg's future and that the Society should be the headquarters and rendezvous of such men. Here they have library and reading rooms and parlors. Here there are social opportunities both in the club life and in the formal meetings for meeting one another and coming in contact with older men, men whose ability or work, or character make their presence an inspiration to young men. Engineers need contact with men as well as with things.

I note by the schedule of appointments that there is a general monthly meeting in the large assembly hall in which papers of general interest are presented by engineers of eminence frequently from distant cities. I find a large number of sections or divisions in which various classes of engineers meet together to take up subjects relating to their specific work, which may be of little interest and consequence to others. Here are the architects, and the chemists, the mining engineers, the civil engineers and the electricians. There are meetings for discussing sanitary problems, for the steam engine, for mill work and others for the problems and methods of bridge design, of building construction and of power distribution in industrial establishments. I note particularly a section consisting of draughtsmen. The chief draughtsmen and their principal assistants meet to discuss the methods of conducting their work more efficiently and simply, and they consider together the problems of interest which occur in their work. I learn that the methods and devices of particular merit which were formerly known and practiced, some in one place and some in another, have now become universal so that each draughting room has profited by the experience of the others and all are more efficient. Uniformity in methods and system is further beneficial when drawings are exchanged from one works to another and the draughtsmen who go from place to place are more efficient in that they work in accordance with the same methods.

I am told that the spirit which prevails is the spirit

of helpfulness and that the members find that he who assists others greatly benefits himself. I learn that the Society has not only broadened by internal development, but that it has affiliated with it other organizations which meet in its halls. There is the Railway Club, consisting of the engineers and others connected with the operation of railways. There are other organizations of men whose work is closely allied with that of the Society, such as the Foundrymen's Association and various other similar bodies composed of men in different branches of industrial work. I learn that the sections of the Society have their monthly and sometimes semi-monthly meetings and in some of the branches there are two divisions, one advanced and the other of young men who are beginners and who find it profitable to meet together and compare experiences and discuss the problems which they are encountering. The Society meetings are supplemented by visits to factories and enginering works in the vicinity. I learn that the Society is the recognized head and center of engineers and engineering work, and it affords the facilities both for the specific pursuit of one's own line of work and also for broadening its members through the general meetings. I note furthermore that the Society is not isolated and purely local, but that it has close affiliations with various national engineering societies. Several sections of the Society are also local sections of the national bodies. There are stated meetings at which the papers presented at the national meetings are reviewed and discussed. At the general meetings of the national societies are representatives from the local society contributing to the meetings and bringing back the inspiration which comes from association with fellow engineers.

I learn that the unfication of engineers through this utopian Society has developed a new spirit among engineers. They recognize that there is an engineering profession and they feel the inspiration and strength of unity and co-operation. They are no longer scattered engineers, they are a concentrated positive force. Through the Society they have advanced individually in their several lines of work. Engineers in different work have learned to co-operate and achieve common results more efficiently. New engineering methods have been diffused, experiences have been interchanged. Standards of various kinds have been adopted. The

elements which have been found successful in one place have become known and are used in other places. There is greatly increased efficiency both of the individual and of engineering methods and work in general. But more than this, as engineers have come to respect themselves they are more respected by others. The profession has a new standing. Engineers united are a force in influencing and moulding public opinion, in undertaking public improvements, in advancing the general welfare.

IS PITTSBURG A MODEL ENGINEERING CITY?

But let us return from this vision of the future to the present and note by a few specific illustrations the present influence and activity of the engineer. I have pointed out at some length that upon which we delight to pride ourselves, namely, that Pittsburg is a city of engineers. Notable throughout the wide world are the industries of Pittsburg, colossal in extent, magnificent in their productions, ever increasing in the efficiency of their work. Pittsburg may therefore be looked to as a model city in so far as its engineers can make it so, but what are the facts? The public works of the city in their construction and operation are to a very large extent engineering matters. The bridges, the streets, the water supply, the sewerage system, the parks and all that go to make up the material basis of the modern city, these are strictly engineering matters from beginning to end. Upon their prompt and economical construction and upon their effective and efficient operation depend the comfort, the safety, the health, the prosperity of the people at large. Do we find in the city of Pittsburg, Pittsburg notable for its engineers, a model city? Does the fact that it ranks high among the cities of the country in its death rate from typhoid indicate that its water supply is all that its engineers can make it?* Does the fact that its highways are rough and dirty and that many streets are left in unfinished condition season after season indicate that this city is the work of engineers? Within five minutes' walk of the Court House, at point where the foreign population is disgustingly dense, back between the houses in a little court yard there is a little shed which will hold just ten

*The deaths from typhoid fever are about 400 per year.

cows. Eleven cows are there, ten inside and one outside, and they supply a local dairy. Within almost a stone's throw of the Union Station in a little court yard which is common to several families are a hydrant and a sink hole which continued to be used in common, while there was small-pox in one of the families.

Is it a credit to the city of engineers that its sanitary conditions are such as any sanitary engineer, or any other engineer, would condemn? Are our public works a credit to our city, have they been well designed, economically constructed and are they efficiently operated? Do you reply that our municipal system is operated upon a political and not an engineering basis, and do you blame the faults upon the men in the city administration? That does not cover my point. I am not condemning officials. I am asking the engineers of Pittsburg whether they like the public engineering of Pittsburg, whether they approve the way in which the city's affairs are conducted. Are the methods and engineering ability employed in carrying out its engineering work, and are the methods by which its general affairs are administered such as would bring successful results if applied to a manufacturing corporation? How are its large problems being solved—its problems of the future?

Pittsburgh is reaching one limit—a limit in its transportation facilities. What plans are outlined for additions to our railways and the improvement of our water ways? Does broad, far-seeing policy prevail and overpower the selfish present interests of corporations and of individuals which threaten to hamper every great project and endanger the general welfare? If not, who is to blame? The politicians? Why not the engineers—primarily the engineers? Are they not citizens? Have they not rights? Have they individually or as a unit—as a unit with a strength which even they themselves do not realize—made any effort to exert a force in public affairs? Do the men whose work in the industries of Pittsburg is one of the wonders of the world, quail and falter before the political boss? Is the politician after all greater than the engineer? Or is it not that engineers, like other good people, lack in civic spirit, they are inactive citizens, they are not united, they

do not exert a postive force in public affairs—a force to guide and direct ordinarily, but to irresistably oppose when necessary? Fellow engineers, if we leave public affairs to our politician brothers, let us give them due credit for their successes, but let us remember that it may have been the lack of a civic force which we might have exerted which has prevented the city of engineers from being conducted upon an engineering basis.

PITTSBURG'S FUTURE DEPENDENCE UPON ENGINEERS.

We have noted how the accelerating advancement of the present is leading to larger problems in the future. Nothing has been more manifest from the experience of recent years than that the future will demand engineers and artisans of increasing capabilities and skill. What provision is being made to procure these men? Are the boys of Pittsburg being cultivated and trained for our industries? Are the young men being instructed in the things which intelligent and skillful workmen should know, and are others receiving the broader education which will fit them for engineering work? We have built costly boulevards along rocky ledges and across the distant hills. Has the city expended millions for the technical training of its youth as an investment which may bring marvelous returns in future industrial supremacy? What has become of the wealth which the engineer has produced? Has not the magic of his touch transmutted the base metals into gold—when the ore changes into flowing metal, when the ungainly mass is rolled into a smooth plate or a long beam, when the rough casting is transformed into the finished machine, is there not also a flow of gold, some to the workman, some to the engineer, and the overflow to the owner? The farmer saves from his surplus the best seeds for the coming season. How much of the surplus wealth is returned to train men for the coming years? Scores of men have made millions. All the manual training and technical and engineering schools in Allegheny County—and there are some good ones—are so small and so insignificant in comparison with what there should be, that they count for almost nothing.

A SOCIETY BUILDING.

How much of the millions to which the work of the engineer has so largely contributed have returned—not to provide for the future—but in recognition of the obligations to the engineering profession of the present? How many hundred thousand dollars have been thrust upon the Engineers' Society for a building which engineers could call their own? Do we need a building? Our present average attendance exceeds the seating capacity of our hall as it was a year ago and is nearly up to its enlarged capacity. At a recent meeting 35 men stood for an hour and a half. The members elected the past year will more than fill the hall, and we are just at the opening of a new era. I cannot for a moment doubt but that the funds will be gladly forthcoming when we demonstrate that we need them and can use them efficiently. Until we can do that, we need cast no reflections upon those who have not come forward to proffer undeserved aid. To him that hath shall be given! Have we now the ability to use well the facilities for a larger activity? I believe we have.

THE TECHNOLOGICAL SCHOOL.

I must return to the question which is yet unanswered. What is being done for the training of Pittsburg's future artisan and engineer? Men differ in their estimate of the value of an education, but I take it that the differences pertain more to kinds of education than to education itself. There is a kind of going to college which does not educate, which unfits rather than fits men for active life. The dilettante fop, the college bum and the narrow book worm who loses all practical bearings are not efficient men for active, substantial work. There is evolution in education as in all else. The efficient education for the men who are to operate the future Pittsburg is not the education of the far away college. It must be a new education, a new kind of an education. It must be worked out here in Pittsburg for Pittsburg. I have not seen, you have not seen it, it does not yet exist.

Andrew Carnegie—the man who preaches a new Gospel of Wealth, and who practices what he preaches—proposes that Pitts-

burg shall have such a school, the great school, and his offer is understood to be limited only to the requirements of a yet unmeasured demand.

How has that offer of unexampled generosity, of exceptional foresight been received? How many years has his other proffered contribution to Pittsburg's welfare, the extension to the Carnegie Institute, been delayed—how long have large things been held back by selfish interests and red tape? How has the city, which well might have invested its own millions in the technical education of its future citizens, responded to an unprecedented opportunity? Mr. Carnegie requested only the ground on which he might plant the greatest thing in Pittsburg. After long waiting there is an occasional echo of entanglements, but there are no reports of effective action. It is whispered that somebody has city lots to sell. I cannot vouch for the facts and I have heard no names, but if it be so, if there be a man who would retard the progress of this great movement, who would restrict its usefulness and scope in the future, who would strike a blow at the engineering profession and at Pittsburg's possible development, who counteracts the effectiveness of a generous gift of millions in order that he may selfishly add a few thousands to his own unearned increment, I say as President of the Engineers' Society of Western Pennsylvania, as an engineer, as a citizen of the city—shame on him. Better he who would steal his thousands directly from the city treasury than the man who would get his money through political machination or sinister influence, and in doing so would blight a great movement for the advancement of his fellow men.

But why, I ask, has so little been done? Whatever the superficial reasons may be and whatever the plausible excuses which may be forthcoming, I suspect that the delay and the bickering might long ago have ceased had there been a definite positive force exerted to secure prompt action. Were there a civic sentiment which would put into our city council men who would look to the higher life of the city rather than to the present welfare of some party or some faction; were there an intelligent public interest which would insist upon action with a force which must be respected; were those who will be directly affected—the stockhold-

ers and managers of our financial and industrial institutions—awake to what such a school means; were the workingmen whose sons would be benefited brought to realize what is lying dormant while their boys are growing up; were those who should be most concerned—the engineers of Pittsburg—alive to the situation and active to create the sentiment and the moral force which would demand action—then Pittsburg might no longer remain under the cloud of disgrace which now rests upon her.

THE COMING YEAR.

Fellow engineers of Pittsburg, we enter upon a new year. The unprecedented achievements of the recent years are the foundation for an accelerating progress. The engineer has now a wealth of experience, of scientific discovery and invention, of recently developed methods and processes which give him new power; modern co-operation in financial, commercial and industrial affairs has broadened their scope and calls for engineering work on a larger scale. The tendencies of the past projected into the future indicate a larger opportunity, a higher responsibility. Let us, who are privileged to live in this age of advancement, in this country of activity and in this city of engineering industry rise to meet the expanding opportunities and the enlarging responsibilities as engineers, as citizens, as high minded men. Let us make our Society the means to noble ends—to our individual development, to the advancement of the engineering profession, to the progress of our city and of our country and to the maintaining of material prosperity, which is a condition of higher, nobler and fuller life.

At the conclusion of Mr. Scott's address the newly elected president was conducted to the chair and spoke as follows:

It is needless for me to say that I appreciate the honor you have conferred upon me. It was unexpected, as I felt that there were so many who were better entitled to it by reason of their services to the Society, their years, and their qualifications, to fill the office.

As you have seen fit to elect me your president I can only say that it is up to us, the newly elected officers, to do the best we

can during the term of our office. It would be foolish to announce that we would do this or that, but we can promise to advance the interests of the Society to the extent of our ability.

There is one statement which I wish to make right now. Unfortunately I have a poor memory. I may meet a member and may hear his name, perhaps imperfectly, but when I wish to recall it, I cannot. If I do not recognize a member, I trust that he will not think that I do not wish to. That is not the reason, it is my poor memory for names and faces; it is not intentional.

We will now proceed to the discussion of Mr. Scott's paper.

Mr. Swensson—I do not wish to discuss Mr. Scott's paper, but I move that a resolution of thanks be tendered the officers who have conducted the affairs of this Society in such an efficient manner during the past year.

Mr. Engstrom—I second that motion.

Upon vote resolution was carried.

Mr. Engstrom—Referring to the papers read during the past year, one-half of them were read by men who were non-members. Why are they not members?

Mr. Hirsch—As a member of the Program Committee I might say that we worked very hard to prepare good programs. We often wrote 30 to 40 letters a month, to many of which we received no response. I think a good many members must have thrown theirs in the scrap basket. I believe I wrote one to Mr. Engstrom, to which I received no response.

The President—I feel that the Society has been just in recognizing the good work of the officers and committees of last year. I think some of the new members should be placed upon the committees. It will encourage them and be of benefit to the Society; but it is necessary for the new members to make themselves known.

What has been said of new members of the Society reading papers here has been true of other years as well as the past year. I have talked with a number of engineers who stand high in this city during the past few weeks who are not members of the Society, and three of them stated that they had never been asked to join. I think that every member of the Society should ask

their engineer friends to join the Society. It is for each one of us to do our duty in this matter.

But we are to discuss Mr. Scott's paper, and I would ask Mr. Brashear to say something regarding it.

Mr. Brashear—Mr. Scott asked if the engineers were not citizens, if they had no rights, if they were not politicians, why not? I might say that I do not think that those in authority care much for the engineers of the city, or for the Engineers' Society of Western Pennsylvania.

At one time I was appointed by this Society on a committee with Captain Hunt to talk to the city authorities. I remember as we entered the office of the Director of the City Works we were asked to wait in an outer office. After waiting, as I remember, a few hours, we were ushered into the august presence and permitted to bow before the King. I wish you all could have been there.

Captain Hunt opened the bombardment, but we came out second best. The reason? We had entered as members of the "Engineers' Society" without money and without price. We were told that our advice was not wanted. I have never consented to serve on a committee to go before the Department of Public Works since that time. Notwithstanding, I think what Mr. Scott said should sink deep into our hearts. We should endeavor to wield all the influence possible to insure better engineering work in the city and to prevent inferior work.

In relation to what has been said of the Technical School, every word is true and should be read by every member of the City Council. I am a member of the Technical School Committee and may say that I spend often 5 to 10 hours a day on the work. We have studied the work of many schools ranging from the Massachusetts Institute of Technology to the Pratt Institute of Technology in Brooklyn, and we want to establish a school that is second to none in the world; but the city does nothing towards fulfilling the conditions of Mr. Carnegie's offer. There has been nothing but disgraceful delay. I believe some men in the city council are honest and in earnest and wish to conscientiously in-

vestigate, but what about the majority? If we are going to have a technical school we must have ground. The citizens want it, but councils will not take action. What can we do but simply wait?

THE PRESIDENT—I wish to say a word that may correct the receiving of a wrong impression by some of the members or visitors present. I do not think that Mr. Scott intended to cast any reflection upon any engineers in the employ of the city. They are certainly not responsible for the doings or misdoings of the City Council. I am sure Mr. Scott did not intend to cast any reflection upon the city engineers.

MR. DAVIDSON—I was very much impressed with the address of Mr. Scott. His idea of increased membership and owning our own quarters appeal to me strongly. I have long been interested in the project of the Society owning its own quarters. I believe this end could be best gained by increasing the membership. We should pack this Society so full that standing room would be at a premium and that members would be standing in line from that door to Sixth street clamoring for admission. If that were the case, we would have a building in a very short time. Now, then, if this idea is a correct one, if we are in earnest in regard to wanting quarters of our own, why not start the movement to-night, now? Why not have every member promise to bring in another member before the next meeting? If each would bring in one member during the year it would mean a great increase in membership. This is not an impossibility. It may be accomplished if we unite in our efforts. Will we?

If we did, before this time next year we would have 1,000 members and the following year 2,000, and that would mean that it would not be long before we would own our own quarters.

Upon motion, properly seconded, meeting adjourned.

C. W. RIDINGER, *Secretary.*

CHEMICAL SECTION—ANNUAL MEETING.

The 11th annual meeting of the Section was held Thursday evening, January 22nd, the chairman, Dr. K. F. Stahl, presiding. The minutes of last annual meeting were approved. The Secretary reported an average attendance of ten, few papers, but a number of abstracts and general discussions thereon, as well as upon different subjects of interest to the Section.

The Section cordially welcomed the presence of Mr. Chester B. Albree, Chairman-elect of the General Society, who made an address counselling activity and perseverance, extending encouragement and promising co-operation. Stress was laid upon the qualities of variety, cordiality and enthusiasm as factors in the future success of the Section. Lines were indicated along which the Section might be brought to new life and enlarged usefulness.

The address of the retiring Chairman then followed: "Some Recent Improvements in the Manufacture of Sulfuric Acid." The address was of much interest, and it is to be hoped that other papers along the line of industrial chemistry may be forthcoming during the coming year. The subject of the address was discussed by Messrs. Albree, Phillips, Camp, Loeffler and McKenna.

The Secretary read the names of the nominees for office for 1903, as presented in the report of the nominating committee at the November meeting. The Secretary, upon motion, was instructed to cast a ballot for the Section for election of these officers, and the following were declared elected to serve during the ensuing year: Chairman, Mr. H. W. Crover; Vice Chairman, Mr. George Loeffler; Directors, Mr. J. M. Camp, Mr. J. A. Mohr; Secretary, Mr. C. H. Rich. Upon motion the annual meeting was adjourned.

CHAS. H. RICH, *Secretary.*

Address read by the retiring Chairman of the Chemical Section:

For the subject of this paper I have selected some recent improvements in the manufacture of sulphuric acid. A subject with

which I am familiar and of which I will present to you from the recent voluminous publications a short description.

Before going into the subject of this paper, I think it advisable to give you a short description of the process in use, as I can not assume that all of you are familiar enough with it to appreciate the far reaching effect of these improvements.

The raw materials for the manufacture of sulphuric acid are either:

Sulphur, or as it is commonly called "brimstone," containing 97-98% S.

Pyrites, that is iron pyrites, which in the pure state as Fe S2, contians 46.67% Fe and 53.33% S, but the commercial article contains besides the main constituents also copper, arsenic and other metallic and non-metallic admixtures. I mention the copper because it influences the value of the pyrites very much. If present in small quantities, say below 3%, the amount is too small to extract it profitably and its presence makes the resulting cinder almost unsaleable to blast furnaces. The other impurity I mention, namely, arsenic, is for many applications objectionable in the acid produced by the old sulphuric acid process and in the new process it exercised an almost unsurmountable obstacle to its successful operation.

Zinc blende Z. S., furnishes large quantities of sulphuric acid in Illinois and Kansas. Zinc blende is, however, not roasted for the purpose of obtaining the acid, the latter forming a by-product of the metallurgical operation of the zinc works.

Locally some other raw materials, by-products from other industries, are used for acid making.

Brimstone, pyrites or blende are burned or roasted in suitable furnaces, the resulting sulphurous acid conducted through a tower called after its inventor, Glover tower, into leaden chambers, where the sulphurous acid is oxidized to sulphuric acid, which collects at the bottom of the chambers, the remaining gases finally pass through one or more towers, named after their inventor Gay Lussac towers. To facilitate the oxidation of sulphurous acid, it is necessary to work with an excess of air, to introduce nitric acid, in one form or other and steam. The object of the Gay Lussac

towers is to absorb the niter gases leaving the system, in sulphuric acid of about 60° Be. These niter gases are liberated again and returned to the process in the Glover tower. The oxides of nitrogen act as transmitter for the oxygen of the air to the sulphurous acid and with proper apparatus there should theoretically not be a loss of niter, but practically there is, varying from 2% to 4% of nitrate of soda calculated on the sulphur burned. The main causes for this loss are: 1. Reduction of the nitric acid to nitrous oxide N_2O. This gas will not reoxidize again, will not be absorbed in the Gay Lussac towers and consequently be a total loss. 2. Absorption of niter gases in the chamber acid, which is drawn off and sold as such, or further concentrated. Chamber acid, even under the most favorable conditions, will absorb some niter gases, which are finally lost for the process, but under abnormal conditions this proportion may be increased many times. 3. Incomplete denitration in the Gay Lussac towers of the gases leaving the chambers. This is the source of the largest losses. To avoid it not only large and well constructed towers and auxiliary apparatus are required, but the process must be regulated with the greatest care.

I have gone into the niter question a little more fully than would be jusifiable for introductory remarks, because it forms the main difference between the chamber and contact process.

Numerous attempts have been made to improve the chamber process and these have been successful in increasing the output for a certain chamber space and decreasing the niter consumption. The chamber space necessary for the complete oxidation of the sulphurous acid is large and is usually expressed in cu. ft. chamber space for one lb. of sulphur burned in 24 hours. Some years ago it was considered good work to get along with 20 cu. ft. of chamber space per lb. sulphur burned, but now there are acid works using only 12 cu. ft. Even with such a diminished chamber space it requires enormous chambers and buildings for sulphuric acid works. For instance, to produce 25 tons of chamber acid equal to 15 tons of 66° acid requires a building of say 75x130 ft., exclusive of the furnace building.

Some of the proposed improvements in acid chambers, such as circular chambers in place of the usual square shape or inter-

mediate towers between the chambers or the complete replacement of the chambers by reaction towers are still more or less of an experiment, although it seems quite certain that by the adoption of intermediate reaction towers the chamber space can be materially decreased.

Numerous improvements have been made in the construction of the towers at the beginning and end of the chamber system, these have made it possible to work with a smaller consumption of nitrate of soda or nitric acid than formerly.

About three years ago the news fell upon the acid workers of the whole world like a thunderbolt out of clear sky that the Badische Anilin und Soda Fabrik in Ludwigshafen on the Rhine had torn down their acid chambers and were making all their sulphuric acid by the contact process. To understand this you must know that these works produce probably twice as much sulphuric acid as any single factory in the United States. It would require about 15 large sets of acid chambers to make the acid which they produce without acid chambers and of all this enormous undertaking practically nothing had leaked out. It may have been that a few outsiders had an inkling of what was going on, but the secret was exceedingly well guarded. It became known to the chemical world by the patents which were granted to the Badische in all industrial states. I am informed the immediate reason for patenting the process was the attempt of a former foreman of the Badische to sell the process to other works. The man, however, knew not enough of the process to induce anyone to buy it, the Badische soon found out what he was doing and then hastened to protect themselves by making application for patents. They were immediately followed by the zinc works of Schroeder & Grillo, Höchster Farbwerke and the Verein Chemischer Fabriken at Mannheim. Each one of these patentees attempted to attain the object in a somewhat different way. The principle of the process was known and contained in publications of Prof. Clemens Winkler of 1875 and following years. Winkler made his experiments with a view of producing the so-called Nordhausen acid by a cheaper process. He employed at first the vitriol stone used at Nordhausen and conducted the gases result-

ing from heating it to a high temperature over platinized asbestos, thus recombining the SO_2 and O and then absorbed the resulting trioxide in commercial sulphuric acid. His experiments seem to prove that it was necessary for the process to have SO_2 and O in stochiometrical proportions, he therefore used a cheaper source for these gases, commercial sulphuric acid, which he decomposed by heating into SO_2, O and H_2O. The water was removed from the mixture of gases and these reunited into SO_3 by passing them over heated platinized asbestos.

Winkler's process just came in time, the organic color works were needing larger quantities of fuming acid and anhydride than the only existing works of Stark at Nordhausen could supply. They took up eagerly Winkler's process just as he had published it and I believe also patented. Winkler kept on working to cheapen the process by using the gases from the roaster gases of the Freiberg works and he was partially successful, but could not overcome the many difficulties to commercial success that he seems to have dropped the subject, at least he did not publish further results. The color works who were using his process evidently took up his work, but they kept their results to themselves and the outside world did not hear any more about it until they were forced to protect their inventions by patents.

Several publications followed later, the most noteworthy is the lecture of Dr. Rudolf Knietsch, of the Badische, delivered a year ago to the German Chemical Society in Berlin. This paper gives an idea of the enormous amount of work which had to be done before the process was perfect. Obstacles presented themselves which would have discouraged almost any other chemist, and which even Dr. Knietsch would not have been able to overcome if it had not been for the liberality with which Badische encourages research work.

He first used gases from the pyrites kilns, which he conducted to the laboratory in a long lead pipe. These laboratory experiments gave very satisfactory results, the conversion of SO_2 into SO_3 was nearly complete and the platinized asbestos retained its activity, but when these experiments were repeated on a large scale the contact substance lost its activity in a short time,

although the gases were seemingly purified as well as in the laboratory experiments, even passing through dry coke and asbestos fibre did not improve the condition. The main source of the trouble was found to be the arsenic, which is present in varying quantities in all pyrites. At Ludwigshafen they used most likely Spanish or Portuguese pyrites containing up to 0.5% arsenic. This is all driven out in burning the pyrites as arsenious acid and the white cloud of sulphuric acid which is always present in the burner gases seems to be the carrier of the arsenious acid. To remove the sulphuric acid from the sulphurous acid gases the latter were carried through long iron pipes and it was found advantageous to cool the gases slowly. As the sulphuric acid in the gases was concentrated, it was not feared that it would attack the iron. But in spite of the seeming purity of the gases, leaving the iron pipe, the substance lost its activity gradually. The cause was again found to be arsenic and the explanation given by Dr. Knietsch is that through the action of the precipitated acids on the iron of the pipes arseniuretted hydrogen was formed, which afterwards was decomposed again by the platinized asbestos and rendered it inactive. The trouble seemed to be overcome when contact between the gases and the metal of the pipes was prevented, but a new source of contamination developed when the furnaces were forced more in the shape of fumes of sulphur, which resisted all attempts to condense it. These fumes of sulphur contained arsenic, which destroyed the activity of the contact substance. After many fruitless attempts to completely remove the sulphur it was found that so simple a remedy as blowing steam into the gases leaving the pyrites burners would not only completely burn and thus remove the clouds of sulphur, but also assist in condensing the acid fumes and prevent the formation of hard crusts of flue dust in the pipes.

The purified burner gases are passed through vertical iron tubes containing the platinized asbestos on perforated trays, which are arranged on a rod and the resulting SO_3 is either condensed as such, or absorbed in sulphuric acid varying in strength according to the percentage desired in the final product. Sulphuric acid containing 97 to 98% H_2SO_4 is the best absorbent. 450° C

was found to be the most favorable temperature for the operation, which is carried out at atmospheric pressure. The reaction evolves considerable heat, which is utilized to heat the fresh gases to the proper temperature by passing air around the reaction tubes.

Cast iron can not be used for absorbing vessels when fuming sulphuric acid is to be made, because it explodes after being in use a short time. This is most remarkable in view of the fact that cast iron stills are largely used to concentrate sulphuric acid up to 97% in this case it is found that boiling acid below 83% dissolves the cast iron, but acid above 83% or 85% has little action on it and if the casting is perfect it may be used for several months. The fuming acid appears to diffuse into the iron and evolve there sulphurous acid and hydrogen sulphide, which finally breaks the casting. Wrought iron is attacked by fuming acid containing less than 27% of SO_3, but with a higher percentage of SO_3 the acid has practically no action on wrought iron.

The zinc works of Schroeder & Grillo do not use platinized asbestos; they bring the platinum in a fine state of division by mixing platinum chloride with a salt preferably sodium phosphate, this mixture is crystallized, the crystals separated from the finer parts and brought directly into the apparatus, where the heat drives out the water of crystallization and leaves the platinum finely divided. The process of Schroeder & Grillo has been acquired for the United States by the New Jersey Zinc Co. and is in use in three works in Mineral Point, Wis., in Wilmington, Del., and in San Francisco, Cal. At Mineral Point they use zinc blende as raw material and I believe at the other two places they use brimstone. Schroeder & Grillo have patented a dry cleaning process for the contact substances, which consists in passing chlorine through the heated apparatus containing the contact substance, thus volatilizing the arsenic.

The Höchster Farbwerke seem to have worked along the same lines as the Badische, using steam for purification and rational cooling and heating for the reaction apparatus. I do not know how successful they have been on a large scale.

The three firms mentioned use platinum as a contact substance, but the fourth one, the Verein Chemischer Fabriken at

Mannheim, which is close to Ludwigshafen, uses iron oxide as contact substance. For their process it is essential that the gases are perfectly dry and they have patented a special drying apparatus for the air entering their pyrites kilns, but arsenic seems rather beneficial than otherwise for the activity of their contact substance. For the latter they use simply pyrites cinder. It seems that they do not attain as complete a conversion as the Badische, but their process seems so much simpler and cheaper that they may be able to compete with those using platinum.

The technical revolution caused by the introduction of the contact process may be compared to the one caused by the introduction of the ammonia soda process about 25 years ago, which resulted in the gradual abandonment of the Leblanc process. How far the contact process will replace the chamber process is difficult to say. Although it is claimed that the Badische is producing even acid of 50° Be (1.5 sp. gr.) containing 62% H_2SO_4 cheaper by the contact than by the chamber process, it is the general opinion that others, who have to pay the royalty amounting to $20,000 to $40,000 for a production of 20 tons monohydrate per day can produce such acid cheaper by the chamber process. F. Lütty and H. H. Niedenführ, two well known German technical chemists, published March, 1902, an exhaustive article in the Zeitschrift für angewandte Chemio, in which they make calculations as to the comparative cost of acids of different strength made by the chamber and contact process. They came to the following results:

Acid of 50° Be can be produced somewhat cheaper by the chamber process.

Acid of 66° Be (1.835 sp. gr. 93.5% H_2SO_4) can be produced about the same by both processes, because the cost of concentration has to be added to acid made by the chamber process.

Acid of 97% to 98% H_2SO_4 can, however, be produced decidedly cheaper by the contact process.

In conclusion let us examine which industries will be affected by these conditions. The fertilizer industry, which consumes about one-half of all the sulphuric acid produced in this country, uses almost exclusively acid of 50° Be and will therefore

most likely continue the chamber process. The iron and steel industry use either 60° or 66° acid, for these strengths neither process seems to have a decided advantage. The explosive industries and dye works use 97% to 98% acid and the chemical works making their acid will most likely in course of time adopt one or the other of the contact processes. I believe the three contact works operating in the United States make their acid for explosive works.

CHEMICAL SECTION—REGULAR MEETING.

The regular monthly meeting of the Section was called to order immediately at the close of the annual meeting by the Chairman-elect, Mr. H. W. Craver. The minutes of the last regular meeting were approved. The Chairman then appointed the following standing committees for the year: Chemical Literature, Messrs. Phillips, Stahl, McKenna, Loeffler, Handy and Arnold; Methods, Messrs. Camp, Maury and Mohr; Papers, Messrs. Stahl, McKenna and Camp.

Mr. H. E. Walters then presented a paper upon "The Volumetric Determination of Manganese in Iron and Steel."

After a general discussion of this paper, the Section adjourned.

CHAS. H. RICH, *Secretary.*

THE VOLUMETRIC DETERMINATION OF MANGANESE IN IRON AND STEEL.

BY HARRY E. WALTERS.

In the American Chemical Society Journal (24, 1206, 1902) there appeared an article by Stehman entitled "The Determination of Manganese in Iron and Steel," in which the author stated that in attempting to replace lead peroxide with ammonium persulphate and titrating with sodium arsenite, the silver salt of course caused trouble. If, however, the silver salt is thrown out of solution before the titration is begun, as insoluble silver chloride, the determination of the permanganic acid by a standard solution of sodium arsenite may be readily accomplished.

With the exception of the titration the method is the same as that read by me before this Section in September, 1901. While preparing that method the writer also tried to make a titration method, but without success, as the hot solutions were titrated and

the reaction between the excess of persulphate and the silver nitrate caused the results to be high and irregular.

Since the article by Stehman appeared I have doubted the necessity of precipitating the silver as chloride if the solution be cooled before the titration is begun.

In order to prove the correctness of this view a number of samples were taken and treated as follows:

0.2 grams of the samples and a standard steel of known manganese contents were weighed off into suitable test tubes or beakers and 10 C. C. of nitric acid of 1.20 sp. gr. were added to each. The solutions were heated until the samples were dissolved and all nitrous fumes were driven off. 15 C. C. of a solution of silver nitrate equal to .02 gram Ag N. O.3 (1.33 grams of the salt to 1 litre of water) were added to each. About one-half gram ammonium persulphate salt was added and the solutions were heated until the oxidation commenced, and then for about a half minute longer. The solutions were then cooled.

In preparing the iron samples one gram was dissolved in 30 C. C. of nitric acid of 1.20 sp. gr. filtered into 100 C. C. calibrated flask and diluted to the mark. After thorough mixing 20 C. C. of the solution were transferred to test tubes or beakers and a little ammonium persulphate salt added to destroy the combined carbon. 5 C. C. of a solution of silver nitrate (4 grams of the salt to one litre of water) and a little more persulphate were added and the procedure continued the same as for steels.

When the permanganic acid solutions were cold they were treated as follows:

First Series: The manganese was estimated colorimetrically.

Second Series: The silver was precipitated as chloride and the solutions were then titrated with a sodium arsenite solution until the pink color was destroyed.

Third Series: The solutions were titrated with sodium arsenite without precipitating the silver as chloride.

Fourth Series: The solutions were titrated with hydrogen peroxide without precipitating the silver as chloride.

The following results were obtained:

Steel No. 18	.28	.27	.28	.27
" 17	.47	.46	.48	.47
" 11	.53	.55	.54	.53
" 22	.57	.59	.59	.59
" 26	.40	.44	.43	.43
" 33	.49	.49	.49	.49
" 90	.90	.92	.90	.89
" 47	.43	...	.43	.43
Iron S	.19	...	.21	.19
" 712	.22	...	.22	.21
" 713	.23	...	.23	.24
" 716	.24	...	.24	.24
" 828	.16	...	.16	.15
" 813	.13	...	.11	.11
" 829	.18	...	.17	.19
Steel No. 68	.73	.72	.74	.74

It will be observed that the results all agree closely whether the silver was separated or not, and that hydrogen peroxide (as was to be expected) may be used as well as the sodium arsenite.

The end point in all these titrations is not as sharp as might be desired, but I think it is sharper if the silver is not precipitated.

If the silver is not precipitated the titration must be done quickly, as the persulphate and silver nitrate in solution react to reproduce the color if allowed to stand.

Laboratory,
United Engineering & Foundry Company,
Lincoln Foundry Company Dept.

Engineers' Society of Western Pennsylvania.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and thirty-first regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's house, 410 Penn avenue, Pittsburg, Pa., Tuesday evening, January 20th, 1903, at 8:20 o'clock, President Chester B. Albree in the chair and 116 members and visitors present.

The minutes of the preceding meeting were read and approved.

The Board of Direction reported that they had passed favorably on the following applications for membership and present same to the Society:

The President—You have all heard the list of applications for membership in the Society. At the last annual meeting we started out to secure 1,000 members during the present year. We have begun the work with applications from 63. If you have paid any attention to this long list you must have heard the names of some of the best-known engineers and manufacturers, etc., etc., in this city. The reason why they have not been members before is simply because the matter has not been brought to their attention; because we have not shown them that it is to their interests as well as our own, for them to become members and identified with our Society. At our last meeting—our annual meeting—the subject of new members was taken up with vim, and, as you can see by the results tonight, the campaign has been carried on with vigor. As a matter of fact, the attendance at that meeting was not very large, so that the list of applications read tonight is largely due to the efforts of comparatively few men. And there is no reason why the rest of us cannot do as well as Mr. Engstrom and Mr. Brynn.

I believe there was a special committee appointed on "Building"; that is, to consider the question of a building. At the last regular meeting an offer was received from Mrs. Foskett, owner

of this property in which we are now located, and same was given into the hands of this committee. It was understood that they were to consider whether we should take up the option given us to purchase this building. I do not know who was chairman of the committee, but I see Mr. Johnson here, and perhaps he can give us some light on the subject.

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BERTRAND B. ABRY,	Electrical Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. h., 524 Rebecca street, Wilkinsburg, Pa.	W. A. Dick, T. D. Lynch, C. F. Scott.
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EDWIN H. RIGGS,	Draughtsman, American Bridge Co., 51st street, City. h., 5908 Rural avenue, Pittsburg, Pa.	P. Prynn, J. K. Lyons, F. Engstrom.
W. F. SCHLEITER,	Manager Sales, Dilworth-Porter Co. Pittsburg, Pa.	G.W.Schluederberg, E. J. Taylor, A. W. Patterson.
E. M. SCOFIELD,	Pres't National Bridge Co. of Pa. President the G. M. Scofield Co. Bridge Building and General Contracting. h., Beaver, Pa.	C. B. Albree, Ralph Albree, J. M. Camp.

NAME.	OCCUPATION.	ENDORSED BY
GEO. E. SHAW,	Draughtsman Structural Departm't American Bridge Co. h., 345 S. Highland avenue, Pittsburg, Pa.	P. Brynn, J. K. Lyons, F. Engstrom.
B. V. SOMERVILLE,	Prin. Asst. Eng. Maint. of Way, L. W. System Penna. Lines West of Pgh. h., Crafton, Pa.	T. H. Johnson, D. Y. Swanty, R. Trimble.
JOHN H. THOMPSON,	- Manager, - Shiffler Plant, A. B. Co. Forty-eighth street and A. V. R. R. City.	F. Engstrom, P. Brynn, J. K. Lyons.
G. M. TRELFALL,	Asst. Engineer County Road, Engineer's Office, h., Crafton, Pa.	F. W. Patterson, W. F. Miller, V. R. Covell.
WM. VELTE,	Foundry and Machine Business, h., 4807 Atlantic Ave., Pittsburg, Pa.	F. H. Schwartz, Willis Whited, G. S. Davison.
GEO. W. VREELAND,	Assistant Master Mechanic, Duquesne Blast Furnaces, h., Duquesne, Pa.	J. M. Camp, A. N. Diehl, C. W. Ridinger.
K. J. VIK,	Asst. Inspector Structural Work, 244 Fisk street, Pittsburg, Pa.	F. Engstrom, P. Brynn, J. K. Lyons.
ALBERT E. WELLS,	Inspector of Structural Work, 7128 Hermitage Street, Pittsburg, Pa.	F. Engstrom, P. Brynn, J. K. Lyons.
ARTHUR J. WHITE,	Engineering Department, American Bridge Co. h., 4807 Atlantic Avenue, Pittsburg, Pa.	P. Brynn, J. K. Lyons, F. Engstrom.
MARSHALL WILLIAMS,	Mgr. Pittsburg Division, American Bridge Co., Fifty-first St., Pittsburg, Pa.	J. K. Lyons, E. Swensson, P. Brynn.
WM. E. WINN,	- Mechanical Engineer, - Heyl & Patterson, Pittsburg, Pa. h., P. O. Box 464, Pittsburg, Pa.	F. V. McMullin, G. T. Barnsley, C. P. Hidden.

MR. JOHNSON—Mr. President, in the absence of the chairman of our committee, who is Mr. Davison, he has requested me to report in behalf of that committee, which I will do very briefly. At a meeting held after the option in question was obtained from Mrs. Foskett, that is, 30 days from and after January 8th, 1903, the advisability of securing this property was considered. We had a meeting last week, and after carefully canvassing the situa-

tion, the committee was unanimously of the opinion that this property is not adapted to our needs. It would be impossible to make any enlargement of our auditorium as it now stands, and to attempt to put up a new building would not be satisfactory on account of the narrowness of the lot. The committee, therefore, recommends that the offer in question be not accepted.

THE PRESIDENT—You have heard the report of this committee, which is more a report of progress than anything else, since the committee is not discharged by reason of presenting this report. Under our by-laws actual business of this kind comes up to the Board of Direction, and I do not know that any formal action on the part of the Society is required. At the same time it was thought best to allow the subject come before the Society as a whole. Are there any remarks? It seems to me that the committee has recommended the wise course, as our quarters are not large enough for our membership now, and it would be impossible to make them large enough on account of the shape of the property.

The next in order is new business. Is there any new business which should come before the Society?

MR. SCOTT—I wish to offer the following preamble and resolution:

Whereas, Mr. Andrew Carnegie has generously proposed for the City of Pittsburg a Technical School which may afford educational facilities adapted for the peculiar needs of a vast industrial community; and

Whereas, The engineering and technical education of its coming citizens underlies the industrial progress and the continued supremacy of Western Pennsylvania; and

Whereas, It is generally believed that there has not been a ready co-operation on the part of the City of Pittsburg in providing a suitable and ample site for the proposed school; therefore be it

Resolved, That the Engineers' Society of Western Pennsylvania expresses its appreciation of the far-reaching advantages of a Technical School in this city and its willingness to co-operate in such ways as may be practicable in advancing the interests of the school and in expediting its completion; and be it

Resolved, That a committee of the Engineers' Society of Western Pennsylvania be appointed for the purpose of conferring with the committee having in charge the matters pertaining to the plan and scope of the proposed school, in order that it may report to the Society the present status of affairs and recommend to the Society such action as may be expedient.

I would add to this the further condition that the complete committee consist of three members, one to be the President of this Society, with two others to be selected by him.

Motion carried.

The President appointed as members of this Committee, besides himself, Messrs. W. G. Wilkins and C. F. Scott.

THE PRESIDENT—I have one or two little points which I would like to bring up here. I have a communication from Mr. McMullin, which reached me a day or two ago, and which contains several matters well worthy of consideration. The character of the information which Mr. McMullin desires is such that it seems to me it would be well to reply in this public way rather than by personal letter. One of the points was that it would be well to have the transactions of our Society made as public as possible by newspaper notice, etc., etc., since this would not only increase the usefulness of our organization to the public, but be of advantage to us as well. I think this is a very good point indeed, and it is one which we have already arranged to carry out this year.

Another point was that our proceedings are often two months late in publication. This is a matter which is not altogether in the hands of the program committee or the officers of the Society to correct. In fact, most of the trouble in this connection is due to the members who read papers and those who discuss them. Members who read papers frequently do not give us the written matter to go into our publication for three or four weeks after the meeting. When they do send it in it is set up in type and the proofs are returned to them for final correction and to be mailed to Mr. Ridinger, and considerable delay often occurs at this stage. In our discussions we have, as you know, a stenographer to take down the proceedings, and since technical matter is somewhat difficult to take, after the discussion is typewritten proofs are sent to the various members taking part therein for their criticism and

correction before final publication. Unless these matters are attended to promptly by the members I hardly see any way we can correct the difficulty. With proper co-operation there is no reason why two weeks should not be amply sufficient to get out the proceedings in printed form. If every man who reads a paper and every man who discusses it will give this matter his prompt attention and return corrected manuscript, there will be no delay on the part of the officers of the Society. I would especially urge every one of you to bear in mind that all matter of this character should be in the Secretary's hands at the earliest possible moment.

Another point that Mr. McMullin brings up is the matter of Sections. He suggests that we organize a Mechanical Engineering and Machinery Section. Our membership is very diversified. We have all sorts of engineers—even one sky-pilot among them, I believe. The Mechanical Engineering and Machinery Section would embrace those who are particularly interested in the operation and design of machinery of different types and kinds. Mr. McMullin suggests he could easily find twenty members in our Society who would be willing, and who would desire, to join such a Section if started. Our by-laws require some little time to get arrangements of this kind in going order, but it requires no time at all to get those interested together and present a petition for a Section, which petition will go before the Board of Direction at its next meeting to be acted upon in behalf of the Society. I would suggest that a Committee consisting of Mr. McMullin, Mr. Flannagan and Mr. H. M. Wilson be appointed to gather in those interested in that particular branch, and that they arrange to meet one week from tonight and set the ball a rolling. I would suggest also that in order to make the meeting of interest, some subject or subjects be prepared or borne in mind for discussion at that time.

Motion to this effect made and seconded.

In this same connection it seems to me that in glancing over our list of members it would be a very desirable thing if our draftsmen could have a Section of their own. We have in the Society, I am quite sure, at least one hundred men who are drafting or who, while they may not spend their entire time over the drawing-board, have a very great deal to do with it. I am confident

that there are a great many questions of design, etc., which it would be interesting and profitable to discuss. I would like to see a Section of this kind organized in the Society. The topics they might take up are almost unlimited, and I would be glad to hear from some of those interested tonight. Mr. Hirsch, what have you to say in this connection?

MR. HIRSCH—I have nothing in particular to say about it, although the idea seems to me a very good one, indeed.

THE PRESIDENT—Could you suggest a committee for the purpose of organizing a section for this purpose?

MR. HIRSCH—I can later in the evening, perhaps.

THE PRESIDENT—There are two other items of business before we proceed to the papers of the evening. One is that it is incumbent upon the President, at the beginning of his term, to name new committees, and in accordance with the regular custom I have selected the following gentlemen for those committees, all to be submitted to the Board of Direction for their approval. These committees to serve during the coming year, viz., 1903.

STANDING COMMITTEES.

Programme Committee.

S. M. Kintner, chairman; W. Glyde Wilkins, Gerald E. Flannagan, Thomas J. Bray, Jr.

Reception Committee.

George T. Barnsley, chairman; Morris Knowles, Emil Swensson, Walther Riddle, B. V. Sommerville, William L. Jones.

House Committee.

Frederick C. Schatz, chairman; Samuel Diescher, Ralph Albree.

Library Committee.

James M. Camp, chairman; E. K. Morse, H. W. Craver, Willis Whited.

Chemical Section.

H. W. Craver, chairman; George Loeffler, vice-chairman; Charles H. Rich, secretary, C. S.

The success of the Society depends very greatly upon the committees. If the committee men are active and interested in

their work and the individual members co-operate properly, it will greatly assist in giving us a successful year. I hope, therefore, that the members of these committees and the members of the Society will do all they can in every way to further this object.

Another point: In this letter which I received from Mr. McMullen there was a request that the reading-room of our Engineers' Society might be left open two nights per week for the benefit of those who wished to consult the periodicals, etc. I wish to say that our reading-room is open not only two nights, but every night in the week and all day long, including Sundays, and that any member of the Society is entirely welcome to come here at any time and have reference to all the latest technical publications, as well as the proceedings of the various engineering societies and organizations of like character. The rooms are always comfortably heated and lighted, and the members are free to come and go when they please.

Mr. McMullin—I only know that I came up here several evenings and found the doors locked, and nobody answered the door bell. I do not know whether the rooms were heated and lighted or not.

The President—Perhaps, Mr. McMullin, you are not aware that all members will be supplied with a key admitting them to these rooms without the necessity of ringing a door bell. These keys may be obtained upon application to the secretary.

There is just one other point which I would like to bring up. The American Society of Mechanical Engineers publishes an employers' Bulletin, a copy of which I have here, in which there is first a list of the vacancies to be filled, and second, a list of available men who could fill various positions. It seems to me this is a very good idea. It has worked very well indeed with the American Society of Mechanical Engineers, and I believe the Philadelphia Engineers' Club has the same arrangement. The Board of Direction of your Society has thought that we might do something in the same line; say, once per month or three months, make up such a list as I have described. This would enable men who are applicants for positions in engineering lines to get in touch with managers of corporations and busiess men in this vicinity who need such assistance, and thus serve both parties.

If an arrangement of this kind meets with the ideas of this Society I think it would be a good move, and a motion to that effect is in order.

Motion made, seconded, and carried.

MR. JOHNSON—I was going to suggest that as our Society is almost entirely local, that it would not be necessary to print this list. The secretary could keep a sort of register to which employers needing men could refer and ascertain whether any men available for his purpose were listed. This would be less trouble, and serve the same purpose.

THE PRESIDENT—While that may be technically true, Mr. Johnson, it is an unfortunate fact that almost all of us are pretty busy, and could hardly take the time to come down here and make such examination of the list as you suggest. If we have it printed the members have the lists right at hand. It is of course understood that the Society does not guarantee either way, viz., we will not guarantee that such and such a man will fill such a position. We will simply give notice that men of certain qualifications are available, and the employers can make terms if advisable in their judgment.

MEMBER—I would suggest that a page in the printed proceedings be used for that purpose, rather than a separate sheet.

MR. BARNSLEY—I would think it better to have a single separate sheet apart from the proceedings, because this is really a side matter and is but temporary. I am a member of the Philadelphia Club, and in sending out these lists the different items are numbered, which arrangement avoids the publication of any names. I think we had better go to that small additional expense rather than have such a list incorporated in the record of transactions. I hope this motion will prevail, because I believe this arrangement would be of special benefit and value to the younger members of the Society, not to mention the opportunity it affords to manufacturers and managers of corporations to supply their needs.

THE PRESIDENT—A motion has been made and seconded. All those in favor of some such general scheme, the details to be left to the Board of Direction, please so signify.

Motion carried.

THE PRESIDENT—If there is no further business before the house we will now proceed with the papers for the evening.

MR. HIRSCH—Mr. President, just a moment before you go ahead. One of our members, Mr. McKee, would like to make a very brief report giving a comparison of the membership of the Philadelphia Club and our own.

[Mr. McKee read a brief statement as to number of members and increase in membership of the Philadelphia Club of Engineers and the Engineers' Society of Western Pennsylvania for 1901 and 1902, the figures indicating growth being very much in favor of the latter organization.]

THE PRESIDENT—We have tonight a series of papers on the transportation problems of Pittsburg. This will wind up the work of a very efficient Program Committee, which has done a great deal for us during the past year. The first paper which will be read in abstract is rather broad ini ts subject, dealing first with historical and other matters of interest in connection with our railroad systems and coming down to very pertinent questions of the day. This paper is by an engineer well known to all of our members, and who hardly needs the introduction which it is my pleasure to give Mr. Antes Snyder.

PITTSBURGH—HER WATERWAYS AND HER RAILWAYS.

BY ANTES SNYDER.

We often hear the question debated as to who are entitled to the credit of having made Pittsburgh what she is, of transforming her from a frontier trading post to her wonderful development of material prosperity, to a city which originates a greater tonnage than the great sea-port of New York City. In the following paper I will try to sketch the history of the development of Pittsburgh as it is illustrated by the history of the development of her waterways and her railways.

The site of Pittsburgh before her soil was trod by civilized man had the same geographical position, the same natural advantages, the same mineral riches as she now possesses.

The same sun shone and the same rains descended upon her, and the same waterways flowed past her then as now, but what a transformation has been wrought in her. Then she was a trackless wilderness trod only by the wild beasts or wilder men, but now the thriving city of which we are all so proud, filled with a happy and prosperous people.

What was the process of this grand transformation? and what were the means used to bring about the astounding result which we see before us in the city of to-day?

This grand result was produced by the efforts of her industrious and patriotic citizens in the intelligent use they made of her waterways and her railways. The great citizens made the great city, and I shall try in this paper to give you an explanation of how this was done.

Pittsburgh passed through the regular process of development of a frontier town. First, the resort of the wild man, then the advent of the hardy and adventurous trader and the establishment of the frontier trading post, then the establishment of the military post, with the struggling settlement of the pioneers clustered around the fort for protection, and with the advent of per-

manent peace the general growth due to her position at the confluence of the Allegheny and Monongahela Rivers and at the head of the Ohio River, making her the distributing point of a commerce continually growing in importance as her use of her waterways were developed and extended.

The first and all absorbing requirement of the hardy settler was food to eat and clothing to wear, his first efforts were directed toward supplying these wants with that of a permanent shelter for his family. When he was reasonably sure that these would be supplied his next and more pressing want was a means of transportation, as after he had cleared sufficient land to produce the necessary food and clothing to supply his wants there was no inducement to extend his labors, as what surplus he might produce above what was required to supply his own wants would be useless for want of market. There was no limit to the land he might cultivate, but no encouragement to increasing his productions beyond his own necessity.

He was his own farmer, carpenter, blacksmith, tailor and shoemaker. Without a market there was no inducement to produce a surplus and no way to dispose of it when produced, no increase of wealth, no accumulation of capital, no concentration of population, no development of industry or natural resources. In fact no progress as we understand the meaning of the word. The future of the settlement depended entirely upon her facilities for transportation.

Lacking the facilities for transportation the settlers converted their surplus grain into the most portable form they could, which was whiskey, which not only became a regular item of barter, but took the form of a medium of exchange and became the circulating medium in all the towns and villages along the banks of the Monongahela River. A gallon of good old Monongahela whiskey was the equivalent of one shilling. Distilling became a great business on the Monongahela and throughout western Pennsylvania, as the name Monongahela whiskey would indicate. It was a tax laid on this industry by Congress in 1791 to help pay the cost of the Revolutionary War which brought on the Whiskey Rebellion.

Pittsburgh may be said to have had her beginning in 1784,

when there was an extensive sale of lots and out lots founded upon the survey of Geo. Woods and Thomas Vickroy.

At this time there were no buildings outside of the Fort, except a few huts on the banks of the Monongahela river. Mr. Arthur Lee, who visited Pittsburgh in 1794, describes it as "inhabited almost entirely by Scotch and Irish, who lived in paltry log houses and are as dirty as in the north of Ireland or even in Scotland." "There is a great deal of small trade carried on; the goods being brought at the vast expense of 45 shillings per hundred weight, from Philadelphia and Baltimore." "They take, in the shops, money, wheat, flour and skins." "The place, I believe, will never be very considerable."

Another writer, whose name I have forgotten, in speaking of the citizens of Pittsburgh at about that same time, remarks that "certain citizens who were too lazy to cut wood to burn were in the habit of digging coal out of the bluffs opposite Pittsburgh, for fuel."

Pittsburgh was incorporated by the Legislature of Pennsylvania as a village April 22nd, 1794, and as a city March 16th, 1816. Her population in 1796, about two years after her incorporation as a village, was 1,395, which in 1820 — four years after she became a city — had risen to 7,248.

I shall not attempt to give the political history of Pittsburgh, but only refer to it incidentally when necessary to a proper understanding of the history of the development of her industries and her material resources. After the beginning in 1794, Pittsburgh enjoyed a considerable trade with the east. There was a great deal of small trade carried on in goods brought at a cost of from $200 to $220 per ton from Philadelphia and Baltimore. This merchandise was hauled from Philadelphia and Baltimore in Conestoga wagons to Shippensburg and Chambersburg, Pennsylvania; Hagerstown, Maryland, and Winchester, Virginia; and from these points was carried over the Allegheny mountains by pack-horses in trains of 10 to 25 animals tied head and tail to insure their keeping in line as they passed over the mountain trail.

At such great cost for transportation you can imagine how limited must have been the traffic as viewed from our standard, and how few articles would bear such charges for transportation.

From Pittsburgh distribution was made by her waterways, and of these her thrifty and enterprising citizens were not slow to avail themselves, and they made use of them at an early day in her history.

Allegheny County was established in 1788, and at that day all communication west and south was carried on by hundreds of flatboats, sailboats and broadhorns, floating down stream with the current: propelled up stream by poles or by sweeps. The upward passage required continuous labor by the crews of boatmen who did their turns walking the deck with push poles against their shoulders, slowly moving the loaded craft against the current of the shallow stream.

When the water was too deep or swift for poling, ropes were carried forward in the attending canoe and attached to trees on the shore. The flatboat was then cordelled or wharfed up stream and anchored while preparations were being made to repeat the process.

A post route was established between Pittsburgh and Bedford in 1786. Amount received at Pittsburgh during 1790 for postage was $110.99.

The course of trade followed the current of the stream and transportation up stream was very slow, costly and of very small extent.

The merchants of Philadelphia and Baltimore shipped their goods by wagons and packhorses to Pittsburgh, here they were exchanged for the products of the industries of that place which were loaded into barges and floated with the current down the Ohio and Mississippi Rivers to New Orleans, there these cargoes were exchanged for the sugar, rum, molasses and other products of a warm climate, and these in turn loaded into vessels and taken by the Gulf of Mexico and the Atlantic Ocean to Baltimore and Philadelphia. It was probably four or five months from the time the merchant made his shipment from Baltimore and Philadelphia to the time he received the returns from his venture.

The men who handled the barges on their journey down the river from Pittsburgh to New Orleans, sold the barges at New Orleans for the lumber they contained. They worked their way to Baltimore and Philadelphia on the vessels carrying the pro-

ceeds of the lading of their barges, and footed it from those cities to Pittsburgh over the mountains by turnpike.

By 1810 there were lines of barges running regularly between Cincinnati and New Orleans, carrying 50 to 100 tons each, propelled by sails, oars or poles. They required six months to make the round trip. They had full loads each way and charged $120 per ton between Cincinnati and New Orleans.

The citizens of Pittsburgh, depending on the rivers for transportation, became expert boat builders and carried on that industry quite extensively. As early as 1801 they had advanced to the stage of building sea-going vessels. A schooner, the "Amity," was launched from Trascon's yard and loaded with flour direct for St. Thomas. A second, the "Pittsburgh," of 250 tons, was launched the same year and loaded with flour direct for Philadelphia. These were followed by other vessels of 400 to 500 tons, which were loaded with flour and shipped direct to Bordeaux, France.

When in 1810 and in 1811 Fulton and Rosevelt put a steam engine on a boat and demonstrated that they could force the boat and its lading against wind, tide and current, and Peter Cooper put a steam engine on a horse car and was able to push it and its load up a steep grade, they little dreamed of the revolution they had inaugurated in the transportation system of the world.

The introduction of the steamboat worked a great revolution in the transportation west of Pittsburgh. It greatly stimulated the traffic in the river and increased the traffic up the stream, but still the circuitous route from Pittsburgh to Philadelphia by way of the Ohio and Mississippi rivers, New Orleans, the Gulf of Mexico and the Atlantic Ocean, a distance of 4,000 miles, as compared with the 314 miles by turnpike, continued to be used, for though the turnpike had been extended to Pittsburgh and the packhorse had been supplanted by the Conestoga wagon, it still required two weeks' time and cost from $120 to $200 to transport a ton of merchandise between Pittsburgh and Philadelphia or Baltimore.

The wide awake citizens of Pittsburgh were quick to avail themselves of the advantages of the steamboat and the number of

them in use on the waterways was rapidly increased, and in this way was laid the foundation of the present unequaled towage system of the waterways of Pittsburgh, a commerce that gives Pittsburgh the proud position of having a greater tonnage than the great sea-port of New York City.

But this system of transportation by turnpike which formed such a barrier as to force the traffic between Pittsburgh and Philadelphia, only 314 miles apart, to seek a route 4,000 miles long could not be tolerated any longer, and in 1827 the Commonwealth of Pennsylvania commenced the construction of her system of canals and railways connecting Philadelphia and Pittsburgh, which was completed and opened for traffic in 1834, costing $12,000,000.

At the time of the inception of this work there were open and in use in Pennsylvania some 3,000 miles of good turnpike road, all of which were destined to be supplanted by the canals and railways and soon fell into disuse.

This improved system of transportation reduced the cost of carrying a ton of merchandise from Pittsburgh to Philadelphia from $140 and $220, the cost by turnpike and packhorse, to $14 and $22, the cost in 1835 over the complete State canals and railways.

This great reduction of cost of transportation worked a great revolution in the traffic of Pittsburgh and her citizens were alert to take advantage of the opportunities it afforded to promote her growth. A barrel of flour which before cost $14 to transport over the turnpike to Philadelphia, now cost $1.22½ over the State canals and railways.

These State works consisted of the railroad from Philadelphia to Columbia, 82 miles. The canal from Columbia to Hollidaysburg, 172 miles. The Allegheny Portage Railway over the mountains from Hollidaysburg to Johnstown, 37 miles, and the canal from Johnstown to Pittsburgh, 104 miles, making a total length of canals of 276 miles, and of railroads 119, or a grand total of 395 miles, as compared with 4,000 miles by New Orleans, the Gulf of Mexico and the Atlantic Ocean.

As a matter of curiosity I would state that the engineers of the Commonwealth located the line of the Portage Railroad to

follow down the valley of the Black Lick and to join the canal at the mouth of that creek, a few miles below Blairsville, but the Canal Commission had the terminus of the canal changed to Johnstown on the plea that as canals were well established means of communication and railways were only experimental it was sound policy to make the canals as long as possible and the railway as short as possible. Though the route down Black Lick Creek was afterward discarded by the Pennsylvania Railroad when she built her railroad, it is interesting to note how the logic of the best location will finally assert itself and how the wisdom of the early engineers in recommending this route down the Black Lick has been vindicated by the fact that the Pennsylvania Railroad is now building a line down the Black Lick to connect Cresson and Blairsville.

During the nineteenth century a continuous stream of immigrants had been moving into the Ohio River Valley, all of southern Ohio had been peopled and Indiana had become a territory of the second grade. It was to accommodate this constantly increasing flow of emigration as well as to develop the internal resources of the State that the system of canals and railways was constructed. The benefit of Pittsburgh was a secondary consideration and followed because her energetic and public spirited citizens were on the alert to take advantage of these improvements and turn them to her benefit, and this her position at the head of the Ohio River enabled them to do. It was to secure this tide of immigration and prevent its diversion to routes north and south of Pennsylvania which were bidding for it that the State made these improvements, and not for any special benefit that Pittsburgh would derive from their completion.

Even before the commencement of the State improvements, while traffic and travel were handicapped by the great cost of carriage over the mountains by turnpike, Pittsburgh was considered a most prosperous city, for it is related that upon one day in June, 1818, 7,000 emigrants with goods valued at $3,000,000, were in that city waiting for the usual June rise of the waters of the Ohio to enable them to proceed on their journey down that stream. When we remember that in 1820 the entire population of Pitts-

burgh was 7,248, we can realize what a congestion these 7,000 immigrants and their goods produced.

You will see from this, gentlemen, that a congestion of freight traffic at Pittsburgh is nothing new. They had them in those early days of her history when the river men had full sway on her waterways and could do as they pleased without any of those iniquitous railroads to interfere with them, and these congestions have been a yearly occurrence ever since.

I have no doubt that the river men of that day denounced the iniquitous providence which obstructed their highway by failing to supply them at all times with the water necessary to its operation with the same vehemence which they now denounce the iniquitous railways on account of their obstructure by the erection of a few bridge piers in the bed of the river.

By 1830 the canal from Pittsburgh to Johnstown was completed, and though the Portage over the mountains was not then completed, yet Pittsburgh enjoyed a very considerable traffic from that source.

At that time there was constructed and in use in the harbor of Pittsburgh the aqueduct of the canal crossing the Allegheny River with seven spans of 100 feet each, and landing at the foot of Washington, now Eleventh street. From there the canal passed along Eleventh street, crossing Penn and Liberty streets and along east side of Grant street and through Grant's hill by a deep cut crossing and recrossing Try street to an outlet in the Monongahela River.

On the Allegheny City side of the river there was a branch canal extending along the banks of the river through the city and crossing Anderson, Sandusky and Federal streets, and extending beyond Federal street to a point between Craig and Darragh streets, where there was a large canal basin fronting on Lacock street.

From the basin the canal extended to an outlet in the Allegheny River. The theory was that the canal boats would pass, by these outlets, directly into the Allegheny and Monongahela Rivers, and either continue their journey by towage or discharge their cargo directly into the river craft.

The deep cut through Grant's hill was afterwards arched over and converted into a tunnel. I am almost afraid to say so, as I cannot at this time refer to my authority for this statement, but my recollection is that there were not more than half a dozen boats that ever passed through Grant's Hill tunnel.

Large basins were established at Penn and Liberty streets where goods and passengers were received and shipped, and through passengers and goods were carried by drays and omnibusses to the different river landings in preference to using these canal outlets into the Monongahela and Allegheny Rivers.

At this time there was in the harbor of Pittsburgh in addition to the canal aqueduct, a highway bridge crossing the Allegheny River from St. Clair street, now Sixth street, Pittsburgh, to Federal street, Allegheny, and one crossing the Monongahela River from Smithfield street to the South Side. These bridges and the canal aqueduct allowed of 35 feet clearance above low water and were the only crossings in the harbor of Pittsburgh. No doubt the canal men of that day considered the Allegheny River directly in the path of the canal a great obstruction to navigation.

The great reduction in the cost of transportation over the mountains resulting from the opening of the State's system of canals and railways acted as a great stimulus to the traffic of Pittsburgh, so that by 1840 136,252 barrels of flour were shipped east from Pittsburgh that boating season. This at the price of $14 per barrel, the cost before the State's system of canals and railroads were opened for through traffic to Philadelphia would have cost $1,907,528, which in 1840 at $1.12½ per barrel cost $153,284, making a saving of $1,754,244 in that one item alone, thus rendering possible a traffic which before had been prohibited by the great cost of transportation.

Goods shipped by the canals and railroads of the State to Philadelphia required three trans-shipments: First, from the canal to the Portage railroad at Johnstown. Second, from the Portage railroad at Hollidaysburg to the canal; and, third, from the canal to the Philadelphia and Columbia railroad at Columbia.

Early in 1840 an innovation in this method of transportation was inaugurated by the introduction of boats made in four sec-

tions which could be coupled together and towed as one boat on the canal, and at Johnstown, Hollidaysburg and Columbia separated in parts and loaded on the railroad tracks for transportation.

Railroad tracks were constructed at Johnstown, Hollidaysburg and Columbia extending down into the pool of the basins, at these places a sufficient depth to enable each section of the boat to be floated over a car placed on this submerged track and hauled out with the section of the boat resting upon it. It was no unusual sight to see a train of four cars, with one of these boats as lading, standing on the railroad track on Broad street, Philadelphia.

I remember the intense interest with which, when a boy, passing over the Allegheny Portage railroad I examined one of these trains. The front section with its stable containing the team of mules contentedly munching their food of oats and hay. The middle sections with their lading of merchandise, and the rear section or cabin with sleeping accommodations for the crew, with the captain, his family and crew quietly eating their noon day meal, while the family wash was dangling from a line stretched on the cabin deck.

This system was suggested by an immigrant to the west who had loaded all his wordly goods and family on a small boat, expecting to be able to sell his boat at Hollidaysburg, load his goods on the cars, buy another boat at Johnstown and proceed on his journey to Pittsburgh.

When he arrived at Hollidaysburg he found he could not dispose of his craft, and being too poor to abandon it and buy another boat at Johnstown, he was simply stranded. But the railroad men were equal to the occasion, they always are. (I am a railroad man.) They lifted his boat and lading bodily onto a car, hauled it over the Portage railroad and dumped it into the canal basin at Johnstown no worse for its journey over the mountains and ready to proceed on its journey west.

During the ten years succeeding the opening of the State works, the coal and iron business of Pittsburgh and western Pennsylvania grew to large proportions, as viewed at that date. The American Railroad Journal of March, 1846, states that the production of iron in its various forms from the pig, for the year

1846 in Pittsburgh, will be an average of 1,000 tons per week, about one-fifth of this will be in the form of nails.

The citizens of Pittsburgh took a very active and honorable part in the construction of this highway by the State, many of those who afterward distinguished themselves in political and business affairs then occupied subordinate positions on the canal. While I can not in this paper treat of the personal recollection of these men, I think it will not be considered either invidious or presumptuous for me to mention one or two names.

James K. Moorehead, who afterward became a distinguished congressman and manufacturer, began his career on the Juniata division of the canal. The stationary engines which operated the 10 inclined planes on the Allegheny Portage railroad were built in Pittsburgh by the following makers: Linton Rogers, Smith and Mennis, Boyle and Johnston, McClurg, Pratt and Wade, and Stackhouse, Tomlinson & Company. The firm of Smith & Gutherie, of Pittsburg, made the hemp rope used on the ten inclined planes on the Portage railroad; one set which they furnished in 1840 cost $33,826.80, and were calculated to last for one season and one-half. But my acquaintance with the history of these early citizens of Pittsburgh is too limited to go into this branch of the subject if I possessed the ability to do it justice. I hope that this may be done some day by a more worthy and able hand than mine.

The great agency in the development of the railway system of the State was the improvement of the locomotive engine.

In 1832 Col. Stephen H. Long, a graduate of West Point, and one of the U. S. Topographical Engineers, who had made the survey for the Allegheny Portage railroad for the Canal Commissioners of Pennsylvania, was residing in Philadelphia. He naturally became interested in experiments with the view to improvements in the locomotive engines and associated with himself Wm. Norris.

In 1833 the firm of Long & Norris made the first engine that ran on the Philadelphia and Columbia railroad and named it the "Green Hawk," and from all accounts it was not a very successful venture. Their next locomotive was a great improvement on the first, and was named the "Black Hawk." The third locomotive

which they built was still an improvement on the other two, but they failed to give it a name, but as I have already remarked, the railroad men were equal to the occasion, they always are, and promptly named it the "Tomahawk."

The success of Mr. Baldwin with the "Ironsides" on the Germantown railroad, and the "Miller," built for the Charleston and Hamburg railroad, of South Carolina, induced the Canal Commissioners of Pennsylvania to order a locomotive from him, and in 1834 he delivered to the Philadelphia and Columbia railroad the "Lancaster," a locomotive weighing 17,000 pounds, having six wheels. This is the first locomotive which went into regular service on the Philadelphia and Columbia railroad, and on April 16th, 1834, it hauled the train carrying the Governor of this Commonwealth and other distinguished guests on the occasion of the formal opening of the road. The regular trips with passengers between Philadelphia and Columbia, 82 miles, was made in eight hours.

On these State railroads the roadbed was owned and kept in repair by the State, but the cars for both passengers and freight belonged to individuals or transportation companies, who furnished the teams for hauling the cars and paid the State tolls for the use of her railroad, but fixed the charges for transportation as they saw fit.

When locomotives were introduced the transporters paid the State an additional charge for motive power, and for some years the cost to the State of the motive power furnished was $40,000 to $50,000 per year greater than the tolls paid by the transporters for its use.

In the fall of 1835 the first eight-wheel passenger car was introduced. During 1835 there were nine locomotives in use on the Philadelphia and Columbia railroad; seven of these were made by Baldwin and two imported from the works of Robert Stephenson, England. These imported engines were inspected and shipped by Antes Snyder, uncle of the writer. He was a civil engineer, a graduate of West Point, who was engaged on the Philadelphia and Columbia railroad, and was sent to England to inspect locomotives and track material shipped for its use on the State works.

In 1835 the firm of McClung, Wade and Co., of Pittsburgh, built a locomotive engine which was put to work for a trial on the long level of the Portage railroad extending from the head of the first inclined plane east of Johnstown to the foot of Plane No. 2, at Portage station, and then sent to the Philadelphia and Columbia railroad. It was named the "Backwoodsman."

In 1835 over 25,000 passengers were carried over the Portage railroad, 15,437 of whom were west bound. The amount of freight was 52,719 tons of 2,000 pounds, 29,740 tons of which were west bound, 15,439 tons east bound and 7,540 local coal.

Among the rules and regulations adopted by the Canal Commissioners for the regulation of the traffic on her canals and railroad were the following:

"Section 108.—It shall be the duty of the conductors of cars moving with less speed upon the railways, upon notice by ringing a bell, blowing a horn, or otherwise, of the approach of a locomotive engine or other cars moving in the same direction at a greater speed, to proceed with all possible dispatch to the first switch in the course of their passage and pass off said track and then stop until said locomotive engine or other cars moving at greater speed can pass by. The conductors of the slower cars are directed to open and close the switches so as to leave them in proper order. Any person who shall refuse or neglect to comply with the provisions of this regulation shall, for every offence, forfeit and pay the sum of $10."

It must have been a very interesting and novel sight indeed while the horse and locomotive were used indiscriminately on the same track and were struggling for supremacy as the future motive power of our railroads, and the approach of a locomotive engine was heralded by the tooting of a horn. Even at that time right of way was given to the fast horse.

"Section 92.—No car shall carry a greater load than three tons on the Columbia and Philadelphia Railway, nor more than three and one-half tons on the Portage Railway, nor shall any burden car travel at a greater speed than five miles per hour unless the car body and load shall be supported on good steel springs."

Mr. Allen, Chief Engineer of the Charleston and Hamburg

railroad, of South Carolina, gave as his reason for preferring the locomotive to the horse as motive power for his railroad that "you could form a very good idea of the improvement that might be made in the breed of horses, but no man could put a limit to the improvement that might be made in the breed of locomotive engines."

In 1837 the Harrisburg, Portsmouth, Mt. Joy and Lancaster railroad was completed from Harrisburg to Lancaster, this in connection with the Philadelphia and Columbia railroad forming a through railroad between Harrisburg and Philadelphia.

General Simon Cameron was greatly interested in the construction of this link, and traveled through Lancaster county holding meetings and urging his farmer friends to subscribe to the stock of his railroad. It is related that at one of these meetings he became greatly excited while dilating upon the advantages that would result from the building of this line and wound up his speech by saying that he expected to live to see the day that he could eat his breakfast in Harrisburg and his supper in Philadelphia. Shortly after the meeting he encountered one of his hard-fisted farmer friends who remarked: "Well, Simon, it's all right for you to talk that way to the boys, it tickles them, but don't think that you can get us farmers to believe such nonsense as that." Now, General Cameron built his railroad, and not only lived to see the day he could eat his breakfast in Harrisburg and his supper in Philadelphia, but he also lived to see the Pennsylvania Railroad completed from Harrisburg to Pittsburgh and see the day that he could eat his breakfast in Pittsburgh and his supper in New York City.

Thaddeus Stephens, one of Pennsylvania's greatest sons, in advocating the building of the Gettysburg railroad, gave as one of his reasons for its construction: "Its beautiful serpentine course." It was the crookedest railroad ever built, and was named by the irrelevant public, the "Tapeworm."

We should bear in mind that in the early days of the railroads of the State the passenger and freight trains were not run at night, the passenger trains stopping at convenient points to allow a lay over to the next morning, and that the use of the canal and Portage railroad was entirely abandoned during the winter.

The stone house at the head of the Plane No. 6, on the Portage railroad, at the summit of the Allegheny mountains, was one of these stopping places, and old residents of that section delight to tell of the stirring times they had when Black Hawk and his band of warriors stopped there over night on their way to Washington to see the President.

During the suspension of operations on the Canal and Portage railroad during winter, passengers and freight were transported from Philadelphia to Harrisburg and Chambersburg by the Philadelphia and Columbia railroad and connecting lines, and from these places by stage and wagons over the turnpike to Pittsburgh.

The Commonwealth of Pennsylvania had expended some $40,000,000 in construction of a vast system of internal improvements, only a fraction of which she realized out of their sale. Let me here remark that while this was looked upon as a loss, it was not a loss in the sense of so much money destroyed; it was so much money which only changed its ownership among the citizens of the Commonwealth. The aggregate wealth of the State was not diminished, but on the contrary, by the great reduction in the cost of transportation consequent upon the building of these works by the State a vast treasury of natural products were given a value which they did not have before. A great stimulus was given to business all over the State and the aggregate wealth of the citizens increased a hundred fold. Truly it was the best investment of money the State ever made and the wide awake citizens of Pittsburgh did not fail to get their share.

The temptation to continue the details of the development of the internal improvements of the State is very great, but as this paper was to treat of the water ways and railways of Pittsburgh, I shall try to confine myself to my subject more closely, but you will pardon me if I make a little digression before leaving the old Pennsylvania canal. I have continually been struck while pursuing the subject by the reflection that human nature is much the same the world over, that whatsoever be a man's nativity his business environment has much to do in shaping his character. It is the chief factor in making the man.

The student of Horace will doubtless remember how in one

of his satires he describes a journey from Rome by canal to Appi forum. If we would but close our eyes and forget when he describes the conduct of the boatman, that all this was occurring in sunny Italy, we would certainly think it was on the old Pennsylvania canal, that instead of all this happening on the banks of the Tiber, it was on the banks of the Conemaugh.

The development of the man was much the same, whether he lived under the tyranny of the Roman Empire or the freedom of the Western Republic.

But to return to the water ways of Pittsburgh. In 1836 the operations for the improvement of the navigation of the Monongahela River by locks and dams was inaugurated by private capital, but was not completed until 1844 and 1850 on the Youghiogheny. After the completion of this work the traffic on the Monongahela River was greatly increased and traffic from Maryland reached Pittsburgh by the Potomac canal to Cumberland over the Cumberland turnpike to Brownsville and thence by the Monongahela Navigation to Pittsburgh, while the shipment of coal by the river increased in an amazing degree. But the great increase in traffic between the east and Pittsburgh resulting from the great reduction in the cost of transportation soon demonstrated how inadequate was the disjointed system of canals and railways of the State to its speedy and economic handling.

A system of transportation which was as described by the critics of that day: "Frozen up one-half of the time and dried up the other half." Canals and railways whose operations were entirely suspended during the winter, where three transfers were required betwen Pittsburgh and Philadelphia and on which passengers stopped on their juorney over night could not fulfill the requirements of such a traffic. A through railroad operated without inclined planes, operated by powerful locomotives, operated day and night, summer and winter was necessary if this State expected to retain the traffic of the great west and prevent its diversion to the northern and southern routes which were becoming strong competitors for it. The experience of the Commonwealth of Pennsylvania in constructing and operating these avenues of transportation had been so unfortunate from the standpoint of the public treasury, as viewed by the vast majority of her citizens

that by common consent, the construction of such a railroad was left to private enterprise and in the natural course of development the Pennsylvania railroad was chartered in 1846 to build a railroad from Harrisburg to Pittsburgh. The construction of this road was begun at once and prosecuted vigorously and completed in 1854, and thus a through railroad without inclined planes, operatied by locomotives, operated day and night, summer and winter was inaugurated between Harrisburg and Pittsburgh, and forming through connections to Philadelphia, 353 miles in length.

In 1851, before the completion of the Pennsylvania railroad, it cost to transport a ton of dry goods $18, and a ton of heavier freight $9, between Philadelphia and Pittsburgh, 395 miles.

In the summer of 1851 James Burns, State Superintendent of Public Works of Pennsylvania, tells how he met at Duncansville, J. Edgar Thompson, Chief Engineer of the Pennsylvania railroad and asked him: "How he was going to haul cars over the mountains?" He replied: "By locomotives." "Then I saw that the man was a fool. I thought I would see how big a fool he was, so I asked him how long he expected a train to be in running from Philadelphia to Pittsburgh?" "Fifteen hours," he replied. "Then I knew the man was a howling idiot and left him." This illustrates the state of public opinion of that day as to railways. The trouble was that no one, be he engineer or civilian, realized in his wildest dreams, the grand possibilities that lay in the development of the locomotive engine.

My attention was early called to this question of transportation in a very practical way. When a boy, living in the village of Selinsgrove on the Susquehanna. I worked in a foundry at 25 cents per day. There was a failure of the crops, whether it was general or local I do not know, but it made no difference which it was, as we had then only the Pennsylvania canal, no railroads, and our country roads were little better than streaks of mud. Though there might have been an abundant harvest within a few hundred miles we could not have availed ourselves of it for want of transportation. The wheat for the bread of that town and others of like situation was brought from the Mediterranean by vessels to Philadelphia and there loaded on canal boats and distributed to the towns along the canal. A bushel of wheat

cost $2.25, it took nine days' work by me to buy a bushel of wheat and one month of my labor was represented by three bushels of wheat.

I did not at that time bother myself about the laws or principles governing this matter, their practical application was enough for me, but as I grew older this matter came up in my mind and induced me to look into this question of transportation. Whether it influenced me so as to determine my future and made an engineer and railroad man of me I can not say, it did not do so at that time, as the highest paid man in that foundry received $2.50 per day and the height of my ambition was to reach that exalted position.

Such a state of affairs will never in all human probability occur again when our railroads haul a bushel of wheat from Chicago to New York for 15 cents.

While Pennsylvania was busy building her railroad to Pittsburgh the great west was not idle. They wished something better than a river navigation which was frozen up half of the winter and dried up half of the summer, and at the best only served a narrow margin of country along each bank, so that various railway projects were under way, destined to connect Pittsburgh with the west.

The Ohio and Pennsylvania railroad, now the Pittsburg, Fort Wayne and Chicago railway, reached Pittsburgh in 1852 and established its station at Federal street, Allegheny City, and all interchange of through passenger and freight between it and the Pennsylvania railroad was made by omnibus and dray. At this time the Commonwealths of Ohio and Pennsylvania believed in the policy of preventing the running of through trains from the east to the west and vice versa, and in carrying out this policy the State of Ohio fixed the gauge of her railroads at 4 feet 10 inches, while Pennsylvania made her railroads of 4 feet 8½ inches. The cities of Pittsburgh and Allegheny in common with other cities believed in the same policy, and carrying out that policy, which they believed to be so very beneficial to their cities, did all in their power to prevent the extension of the Ohio and Pennsylvania railroad through Allegheny City and over the Allegheny River to a connection with the Pennsylvania railroad. Thus con-

tinuing for some six years the transfer of passengers and freight by omnibus and dray from the Pennsylvania railroad in Pittsburgh to the Ohio and Pennsylvania station at Federal street, Allegheny City, a service which the engineers of the Pennsylvania railroad calculated was equal to the addition of 75 miles to the haul between Philadelphia and Pittsburgh.

The Canal was at that time owned and operated by the Commonwealth of Pennsylvania, and it was only after its purchase by the Pennsylvania Railroad Company in 1857 that the Ohio and Pennsylvania Railroad Company secured the right to cross the Canal, which was necessary for them to do, in order to reach the Allegheny River. The permission of Allegheny City to cross the streets necessary in order to reach the river was accompanied with the requirement of the payment yearly of a handsome sum of money and the condition that the railway company also construct and maintain a foot way on the upper side of the bridge, to be open at all times to the free use of the public.

The bridge carrying the Ohio and Pennsylvania railroad over the Allegheny River was built in 1857 and their track was extended to Penn street, Pittsburgh, and thus was added another of those so called, by the river men, iniquitous railroad bridges crossing the navigable water ways of Pittsburgh.

In 1858 the Ohio and Pennsylvania railroad was extended across Penn street and Liberty streets, and into the Pennsylvania Railroad Station at Grant street. Thus doing away with the vexatious and costly transfers, for while they could not on account of the difference of one and one-half inches in the gauge of their tracks, exchange rolling stock, the transfers were made from car to car standing side by side on the parellel tracks. This extension of the tracks of the Ohio and Pennsylvania railroad over Penn and Liberty streets was very vigorously resisted by a portion of the citizens of Pittsburgh.

I remember, when a young man, residing on the banks of the Susquehanna River, of hearing my father read in the newspapers of the day of the great excitement and tumult in Pittsburgh when that was done, and when I came to Pittsburgh in 1863, this Penn street crossing was one of the first points I visited.

This difficulty of interchange of rolling stock and transfer of

freight and passengers was practically overcome to a small extent, by the organization of transportation companies such as the Union Line, Empire Line and sleeping car lines, who constructed cars with wheels of such a broad tread as enabled them to run indiscriminately either on the 4-ft.-10 or 4-ft.-8½ gauge. But still the great bulk of the traffic was transferred at Pittsburgh. It was not until a number of years later that the cars of the Pennsylvania Railroad Co. ever passed west of Pittsburgh, or the cars of the western lines centering in Pittsburgh ever passed east of Pittsburgh.

In 1863 the Pittsburgh and Steubenville railroad was under course of construction, thus adding another railroad bridge over the Monongahela River in the harbor of Pittsburgh; and what the river men consider the greatest of all iniquities, the railroad bridge over the Ohio at Steubenville.

Meantime the citizens of Pittsburgh were not neglecting her water ways. The fleet of steamers plying upon the water ways had increased in a wonderful way. The construction of the Monongahela Navigation had stimulated the coal trade on the river to a wonderful degree and with the extension of the railways to the west the inevitable struggle between the river and the railways for the traffic of the boundless west had begun and has continued to the present time. But the general traffic which the river lost to the railways in this struggle was more than compensated by the great increase in coal trade which made the improvements of the Monongahela Navigation Co. a very profitable venture for the stockholders. But Pittsburgh did not follow up her success in the matter of the improvement of the navigation of the Monongahela River by private enterprise, by extending it to her other navigable rivers, but with their usual Scotch-Irish thrift they struck a much richer lead and followed it up so successfully that they succeeded in getting the General Government to purchase their improvements on the Monongahela river at a good round price above cost for the same and for the franchise. Thus saddling upon the United States the expense of keeping up, improving and extending a water way which they, the river men, could use free of charge. This was a rich lead and they have worked it successfully ever since. It beats building railways

where you have to expend immense sums of money for rights of way, road bed, superstructure and rolling stock and in their maintenance, and has forever quieted any individual enterprise in the improvement of her water ways. The railways are left, without any nursing, to shift for themselves while the small part of the community who use the water ways, kept up at public expense, and without any compensation for their use, would, if they could, deny the railroads the right to cross this public highway. Not directly, but by fixing such onerous conditions to the right to cross as would not only prevent the railroad, in many cases, from building bridges over these navigable rivers, but would also prevent the populous communities on its banks from building such bridges. These onerous conditions, in addition to the greatly increased cost required to make the structures conform to the same, also impose great inconveniece and loss in the use of the bridges by commerce which crosses them. When made to conform with the requirements of the river men, these bridges would do greater damage to the vast commerce which crosses over them, than their continuance as at present constructed would damage the comparatively insignificant commerce which passes under them.

The navigation of these waters, while it reaches large populations, is confined in its benefits to a comparatively narrow strip of territory on each side of the navigable channel; and if this were the only means of cheap communication it would tend to concentrate manufactures and commerce along the banks of our navigable streams, leaving the rest of the country to get along as best it can. The railroad can be constructed to almost any point, rendering any point in our country accessible, no matter how far it may be from our navigable streams. Of all the inventions of man the railway is the greatest producer and distributor of wealth we know of and its influence reaches the remotest corner of our country instead of being limited to a narrow strip of territory along the banks of a navigable stream. Being made accessible by the railways these distant points are compensated in a measure for the disadvantages of their position as compared with the points on navigable streams, thus preventing too great preponderance of advantages to the latter, giving all an equal, or nearly equal,

chance in the race for business all over our country, instead of concentrating enterprise in a few localities pecularly favored by nature. The railroads by concessions on rates to the less favored points are able to put all sections on a more equal footing, giving to all sections as nearly as can be an equal chance. This is called by many discrimination, but I call it equalization, while to furnish a highway, improved and maintained at public expense and only accessible to a very small part of the public who use the same free of cost, while the general public are compelled to pay the cost of constructing and maintaining the same and at the same time discourage and hamper the other systems of transportation constructed and maintained at private expense by the onerous conditions placed upon them as to the character of these crossings they must necessarily make of these free highways, making these crossings unnecessarily costly to construct and use, would seem to me to be the rankest kind of discrimination.

The complaint of the river men, as I understand it, does not relate so much to the ordinary traffic and exchange of produce and manufactures, but it relates to the alleged interference with coal traffic which forms the great bulk of their trade. Nine-tenths of the accidents at these bridges are due to the overgrown fleets of coke and coal barges which pass down the river. These fleets being often 280 feet in width and 1,000 feet in length, and it is to stimulate and encourage this special traffic that the public are asked to tax themselves to raise millions of dollars to widen, deepen and slack water by permanent dams this river channel for the free use of a comparatively few men engaged in this transportation, and also to spend many millions more in additional cost of structures crossing these navigable streams, rendered necessary by the exactions of these men as to the way they require these structures to be built in order to reduce the cost of their traffic, a small saving to them in this case more than justifying, in their opinion, an enormous expenditure by somebody else in accomplishing that saving. While the increased expense of carrying the traffic across these high and costly structures, together with the inconvenience to the public in their use, is not to be considered when it comes to a saving in transportation to

the river men who already have their free use of a highway constructed at public expense. I say constructed at public expense because, while it is called a natural highway, a misnomer, as I shall try to show you later, and early in the history of Pittsburgh was used as nature left it, by the introduction of locks and dams it has become as much an artificial highway as a railroad.

The claim that the freight congestion at Pittsburgh could be obviated by the removal of a few bridge piers from the river channel and raising to a higher elevation a few bridges crossing those channels, is a fallacy, as these congestions of traffic on the river have existed since it was first used for transportation purposes and are of frequent occurrence at this time, and continue for months at a time when traffic is entirely suspended by too little or too much water, and vast accumulations of freight are held in the harbor of Pittsburgh.

The great fault of the railways seems to be that after handling the traffic successfully winter and summer for 50 years, that though they have not been forced to suspend entirely, as the river men are compelled to do when it stops raining long enough to let the water fall, they have been compelled by an extraordinary and unexpected rush of business which exceeded their facilities to greatly delay their deliveries.

These frequent congestions of the river traffic seem to be taken as a matter of course, while this single failure of the railways in 50 years is heralded far and wide, and river men, while loudly censuring the railways for their one failure in 50 years of successful service, in the same breath invoke the law to compel a lot of innocent stockholders to expend millions of dollars in raising their bridges in Pittsburgh harbor in order to give this river traffic additional facilites for holding the congested traffic, which is the chronic condition of this river route for eight to nine months of the year, and are besieging the General Government to expend many millions of the public funds on the Ohio river between Pittsburgh and Cairo so as to enable them to use this as an additional relief for this congested condition of their traffic, while the railways are spending tens of millions of dollars of their own cash and using their most strenuous exertions to overcome the congestion without asking assistance from anyone.

While the railways all over the United States are expending hundreds of millions of dollars in order to do away with heavy grades and sharp curves, so as to facilitate and cheapen communication and almost every municipality in this broad land is spending what amounts in the aggregate to many millions more so as to do away with summits or humps in their highways. Here the river men are invoking the law to compel the citizens of two populous and thriving cities to spend millions of dollars in order to introduce such summits or humps in each of their present commodious and comparatively level connecting highways.

The river route could not handle this congestion if it were perfectly free from crossings and piers from Pittsburgh to Cairo, because this congested freight neither originates from points reached by the river, nor is it destined for points reached by it. No one claims that the river has reached the limit of its capacity as a transportation route, then why does it not now form a safety value for a part at least of this congested traffic? It certainly will not be contended that the presence of a few bridge piers prevents its use for the relief of the freight congestion of Pittsburgh, though their presence may perhaps render the use of that highway not quite so convenient as it otherwise would be. This freight congestion arises from shipments of coal, coke and other merchandise from points not on or reached by the river navigation, and would and could not be reached by it if it had an unobstructed channel, and is intended for points that can not possibly be reached by it even with such an unobstructed channel. This traffic coming from hundreds of points not reached by the navigable waters and destined to points not reached by the same navigable waters, could not be handled by the river route without being hauled by railroad from the point of shipment to the nearest point on the river and then transferred to boats, then taken to the point on the river nearest its destination and there transferred to the railroad again. Would anyone seriously advocate such a route as a sure cure for future freight congestion as the proper route for the lake trade, for instance?

To say that every limitation of river utilities from Pittsburgh to New Orleans is a wrong to every home, every industrial interest in the Ohio and Mississippi valleys, is a great stretch of

the imagination. What is claimed as a limitation, if it be a limitation, can only affect those using the channel of the river and those on the immediate banks of the same. They would only affect a narrow fringe of territory on each side of these rivers and easily accessible from their channels. The expense of changing these crossings so as to obviate these supposed limitations, and the inconvenience arising from the use of these raised bridges, would more than offset to the inhabitants of this narrow fringe any advantages they might derive from the unobstructed river channel, while the vast stretch of country on each side of this narrow fringe would be forced to use these changed crossings and submit to the inconvenience and expense of their use for all time, and would have nothing to recompense them for their loss. If the inhabitants of the great valleys of the Monongahela, Allegheny, Ohio and Mississippi rivers are to depend on this river transportation as their only way of relief for their demands for increased facilities of transportation, they are leaning on a broken reed.

I refer to these territories because Pittsburgh is the gateway through which a great part of this tonnage for these territories passes, and supposing for the sake of the argument that Pittsburgh might derive some slight benefit from the raising of these bridges and widening of their spans (a conclusion which I dispute), and much as we admire Pittsburgh and believe in her future, we should still remember that Pittsburgh is not the whole United States. The other sections and interests beside her have a right to be heard, and where the injuries to these from the raising of these bridges is so manifest, without any compensating advantage, and the injury to Pittsburgh is so poorly compensated, if at all, by the resulting advantages, it would be the part of prudence to leave matters for the present at least as they are. I think I can understand how the construction of the Lake Erie and Ohio River ship canal might relieve the railroads of a vast tonnage which they now carry to lake ports, but I fail to see how the substitution of higher bridges with wider spans at the crossings of the Ohio, Allegheny and Monongahela rivers would enable the river men to handle the lake traffic. I fail to see how the substitution of higher bridges with wider spans at the crossings of

the Allegheny, Ohio and Mississippi rivers is to affect this transportation question. First, in the vast territory reached by the great lakes and in that between the lakes and the Ohio river, excepting, perhaps, the narrow fringe along its banks. Second, in that vast territory between the Ohio River and the Gulf, excepting perhaps that narrow fringe along its banks. And third, in the vast territory in the valley of the Mississippi River, excepting the narrow fringe along each of its banks.

Every foot added to the length of the spans of the bridges crossing these rivers is so much added to their cost of construction, every foot added to their height is not only so much added to their cost of construction, but is a permanent addition to the cost of moving the traffic passing over these bridges, whether they be highway bridges or railroad bridges, and while this coal traffic, for the convenient handling of which, by the river, all these requirements are asked is very large, it is a drop in the bucket when compared with the traffic which crosses over the Allegheny, Monongahela, Ohio and Mississippi Rivers on the many railway and highway bridges which span their channels, a traffic which affects the whole country from the Atlantic to the Pacific, from the Great Lakes to the Gulf.

The greatest good to the greatest number is a maxim to which we all subscribe, but I agree to it with a territorial limit. In the matter relating to Pittsburgh alone the greatest good to the greatest number should prevail, but I see no reason why the interests of a few Pittsburgh citizens should be sacrificed to the interests of the many of Cincinnati, merely because the latter are the most numerous. There is no good reason why the interests of the many inhabitants of the thriving cities which line the banks of the Monongahela, Allegheny, Ohio and Mississippi Rivers should be sacrificed to the wishes of a small part of those using those rivers as a highway, who are engaged in this coal traffic.

The river trade of Pittsburgh naturally divides itself into four divisions: First, the traffic on the Monongahela River; second, the traffic in the harbor of Pittsburgh; third, the traffic down the Ohio and Mississippi Rivers; fourth, the traffic on the Allegheny River.

The first consists of the gathering together of the vast tonnage of coal from numberless points along the Monongahela River and its tributaries and its shipment to, and assembling in, the port of Pittsburgh, which, for this purpose of assembling this coal and holding it for a raise of the waters of the Ohio, the Monongahela and Ohio, are available from Smithfield street to Davis Island dam, a distance of five and one-half miles, and seems to be ample for the present and prospective wants of this coal trade.

This great coal traffic is rendered possible by the construction of the works of the Monongahela Navigation Co., and has grown to its present vast proportions since the inception and completion of these works. This traffic in its path to the harbor of Pittsburgh passes under many structures in the way of railway and highway bridges, some of these, as the first highway bridge at Smithfield street, were constructed before this river traffic had its beginning, and in spite of the seeming obstructions of these bridges this coal traffic has reached its present vast volume. While this river traffic might perhaps have been conducted more cheaply and expeditiously if the river had been free from all crossings, yet their presence does not seem to have checked its growth. The coal traffic had adapted itself to the conditions as it found them, and in spite of these drawbacks has increased to an amazing extent.

I do not believe these impediments, if you call them such, either limited or impeded this development in the least.

The only limit to its growth was the law of supply and demand, the extent of the market to be supplied and the ability of the producers to supply the demand; any slight drawback that might have resulted from these crossings, if there were any such, were as the result shows easily and quickly overcome.

After passing into the harbor of Pittsburgh this great coal tonnage is divided into two parts, the one, a very small part, being distributed to the various consumers along the river front of Pittsburgh and Allegheny City, the remaining and vastly greater part being assembled in great fleets and held in the harbor of Pittsburgh for a favorable stage of water in the Ohio River for transportation down the Ohio and Mississippi Rivers under the

control of towboats of great power. Many of these great fleets are 280 feet wide and 1,000 feet long, and even with their powerful tugs are very unwieldy and liable to accidents, the liability to damage increasing greatly with the increase of width and length of tows. The great majority of the accidents are not to the crafts carrying the ordinary traffic of the river, but to these overgrown tows of coal barges and boats. But this relates more directly to the traffic down the Ohio.

While the crossings over that part of the harbor of Pittsburgh on the Monongahela and Ohio Rivers may be affected by this vast traffic down these rivers, which pass under them, it can hardly be contended that the crossings of that part of the harbor of Pittsburgh on the Allegheny River is affected by this traffic, or if affected by it, it is only in a very slight degree, and only if we consider that the harbor of Pittsburgh extending down the Monongahela and Ohio Rivers from the Smithfield street bridge to Davis Island dam, 5½ miles, is too limited for the assembling and holding of these large fleets waiting a favorable stage of water for their journey down the river, or may become so in the future. And even if such be the case, is the mere convenience resulting from such an enlarged harbor for holding this coal tontage to offset the inconvenience, damage and loss resulting to the public of Pittsburgh and Allegheny City from being forced to use for all time these high bridges, and the loss to the owners from being forced to abandon their present bridges and build others. The distribution on this part of the harbor has been made in the past and can be made in the future under the present conditions. It would look to be the better and cheaper course to make the few towboats handling this traffic to conform to the bridges than to spend the vast sums of money required to raise these bridges and inflict upon the adjacent property holders the damage that would result, and compel the traffic over these crossings to permanently suffer the cost and inconvenience resulting from such a raising, or is the opening of this part of the harbor of Pittsburgh so as to enable these large fleets to take refuge there during floods such an urgent necessity as to justify the raising of these bridges? The presence of these large fleets in the contracted channel of the Allegheny River or moored along its

banks would be a serious obstruction to the free use of this part of the harbor or its banks for the ordinary traffic and distribution.

The distribution of the coal supply of Pittsburgh is not made in these large fleets whose width and length are made excuse for demanding such long spans in the bridges crossing the Monongahela and Ohio Rivers which they traverse, and the height of the powerful steamboats required to haul these unwieldy fleets is made the excuse for demanding such great height in these same bridges, but the distribution is made a coal barge or two at a time, moved by small towboats, and as there is nothing in the height or length of the spans of the present bridges to interfere with the passage of these barges, there should be very little trouble and expense in making these towboats to conform to the present condition of these bridges on the Allegheny part of the harbor. We should bear in mind that craft carrying this coal trade, whether intended for the through trade down the river or for distribution in the harbor of Pittsburgh, stand only a few feet out of the water and pass with ease under any and all of the bridges spanning the Allegheny. It is the powerful towboats hauling these immense fleets on the Monongahela and Ohio Rivers that seem to call for such extreme heights in the bridges crossing these streams.

It is contended that a rise of 12 feet in the Allegheny River would prevent the traffic passing under such low bridges, as the Union and Sixth street bridges, but would not the current incident to such a rise effectually deter the use of the river under these bridges for traffic at such times, though the height and length of the spans were raised and increased as demanded by the river men?

In the rare case of a rise in the Monongahela River and none in the Allegheny, the height of these bridges might prevent the large fleets of coal boats and their towboats from seeking refuge in the Allegheny, but is the preparation of such a harbor of refuge, convenient only at intervals, such an overshadowing public necessity as to offset the cost, damage and loss resulting from the raising of these bridges? And when we consider the nature of this traffic which would seek shelter there, of which I shall speak hereafter, a traffic that will eventually result in closing the

industries of Pittsburgh, should we consider its convenience as having any weight against the cost, damage and loss to the inhabitants of Pittsburgh and Allegheny City by reason of the raising of these bridges?

As to the traffic down the Ohio River, as I remarked before, the ordinary exchange of commerce between the cities and towns along its banks seems to be carried on very successfully with the present bridges crossing that stream, the great outcry for increased length of spans and height of clearance being for the accommodation of the great fleet of boats and their attendant tugs to enable them more expeditiously and cheaply to deprive Pittsburgh of the coal which is the foundation of her present prosperity and of the growth she may make in the future; and after Pittsburgh, along with the rest of the general public, has taxed herself so that millions may be expended for the benefit of this questionable part of the river traffic, have they not done more than their duty? Why should the general public and all other systems of transportation be required to submit to the additional expense, damage, inconvenience and loss involved in the raising of the spans of the bridges crossing the Ohio and other navigable streams so that this questionable part of the river traffic may be encouraged and stimulated in doing what the public-spirited and patriotic citizens consider as making the beginning of a policy which, though its effects may only be realized in the future, will and must inevitably lead to the final destruction of the industries of Pittsburgh.

As to the navigation of the Allegheny River, much stress has been laid upon the fact that the United States Government has authorized and have under way dams in that river at Herrs Island and Springdale, as if that fact were proof beyond question of the existence of traffic justifying the erection of such dams, when it is a notorious fact that it is often the necessities of politics rather than that of navigation that dictates these appropriations, the desire to influence voters and not commerce that is the chief motive.

Whether that part of the traffic of the Allegheny Valley which the railroads will leave for the river will ever practically justify the great cost of the construction of a slack water naviga-

tion of this stream or even amount to a tithe of the cost of maintaining such a system after its construction, is to my mind an open question.

The river men, land owners and inhabitants along each side of the river dream of a traffic equaling or perhaps rivaling that of the Monongahela Valley, and that this traffic will develop in a very few years if only the bridges crossing the Allegheny at Pittsburgh were raised 20 feet higher than they are, and the United States Government continue to extend its slack water improvements. But have they anything but dreams to base their predictions on? The men of the Monongahela navigation have been some sixty years building up their traffic, and during that time had everything their own way, without any competition on their river or the Ohio, and with the best coal in the world, in seams cheaply mined, as their basis to work on. Does anyone think that the thin vein coals of the Allegheny Valley, inferior in quality and more difficult and costly to mine, can supplant the coal of the Monongahela Valley in Pittsburgh and on the Ohio and Mississippi Rivers, or that the men of the Monongahela Valley will sit down and fold their hands and see their business taken from them by those of the Allegheny Valley? I think that anyone conversant with the situation cannot doubt as to the result of such a competition.

Instead of the traffic from the Monongahela being supplanted by that of the Allegheny, it would result in sending the coals of Pittsburgh up the Allegheny Valley and capturing the home markets along that valley. That whatever hindrance, if any there be, to the traffic on the Allegheny Valley by the present bridges is a protection to the transportation men of that valley instead of a drawback, and that the raising of those bridges might result in the very bitter disappointment to many of its most enthusiastic advocates. You may point to the fact that the inhabitants of the valleys of the Allegheny and Kiskiminetas Rivers are enthusiastic to a man in favor of the river improvements, but why should they be otherwise when they will get a first-class means of transportation, constructed and maintained at public expense, which they can use free of any charge and regardless of the volume of

the traffic, and which will not be their loss should it fail to realize all of their bright anticipations.

The United States Government may find that the perverse public may, to a very great extent, refuse to use this highway, and use the railroads, just as the shippers by the canal refused to use the elaborate and costly means of reaching the Monongahela and Allegheny Rivers with their boats, as prepared by the Commonwealth, and took to the omnibus and drays.

The State of Pennsylvania spent $40,000,000 in a great system of canals and railways, only to become obsolete in a few years, and perhaps the future has the same fate in store for the investment of the United States Government in those improvements. While we may not quarrel with the United States for investing money in such an uncertain enterprise, it does seem strange that she should compel her citizens to expend large sums of money in raising bridges and to submit to the loss and inconvenience of using the bridges after being raised, and all this to be done in anticipation of a large traffic to be realized some time in the distant future, and this realization dependent upon the contingency that the traffic on the Allegheny can compete successfully with, and to a great extent supplant, the traffic of the Monongahela Valley in Pittsburgh and along the Ohio River, the idea being that all that has prevented the men of the Allegheny Valley from doing so is this lack of 20 feet additional head room at the bridges over the Allegheny River at Pittsburgh.

If the demands of the traffic on the Allegheny River are so weak as to be completely discouraged by the present bridges it would certainly go to the wall under the competition of its vigorous, rich and well equipped rival on the Monongahela, should the bridges be raised. To my mind this competition under present conditions has been the great factor that has held back and retarded the development of the traffic from the Allegheny Valley, and the raising of these bridges in the harbor of Pittsburgh would only intensify and extend their competition and result in a further restriction of the traffic down the Allegheny River.

Is there sufficient inducement to Pittsburgh and Allegheny City in such great expectations, resting on such a slim and uncer-

tain foundation, as to justify them in defacing their river front, damaging the property of their citizens and forcing them to expend large sums in raising their bridges, and to submit for all time to the expense and annoyance of the use of these raised bridges?

If nature intended these rivers as natural highways of traffic for the use of man instead of the great drainage channels which they really are, she left them in a very unfinished condition. She made a very bad job of it, and we have been spending millions of dollars in widening, deepening, straightening, and at points narrowing these channels and erecting numerous dams and locks so as to fit them for man's use as a highway for this traffic until without materially impairing their usefulness as the great drainage channels of this country, the use of which nature intended them, we have practically converted them into artificial channels of commerce. The mere fact that these men have seized upon and located their system of transportation upon the drainage channels gives them no rights superior to other highways of traffic located upon dry ground or on the bridges crossing these navigable waters. These are highways as well as our river courses, and are entitled to their rights also.

When man converted these natural drainage channels into highways of traffic they did not acquire any rights superior to other systems of transportation such as would compel all others to yield to them. Their rights, whatever they are, commenced with the time of their improvement of these drainage channels, and cannot, from the fact that these drainage channels existed for all time as such great drainage channels, enable those who utilize them now as highways of commerce to antidate their rights to all others crossing them, though these crossings were made long before the utilization of the streams as highways of commerce.

If there is any right to the occupation of these channels in any one, independent of all laws and State or United States authority, from the fact that they were created by nature, would that carry with it the right to alter these channels independent of all laws?

If there is any such right by nature, how are we to decide who are the favored men whom nature intended to enjoy that

right? Why should those who claim this right to occupy these channels lengthways have any preference over those who desire to occupy them crossways?

If nature created these great drainage channels of traffic she evidently intended that they should be dried up for half the summer and frozen up for half the winter, and to have the many crooks and shallows as we find them, or she would not have made them so.

If anyone desires any right from her, superior to all law, it must be to use these channels as nature made them. Where do they get any authority to fly in the face of nature and alter her highway as she made it? Nature intended these as great drainage channels, and she provided a way to keep them as such in spite of man's interference.

The advocates of the Ohio Ship Canal lay no such claim to rights superior to all other highways, but in their estimate of the cost of that highway they provide for the cost of taking care of all these where the canal interferes with them. They claim no difference in the nature of this right of their highway from the mouth of the Beaver to Niles, where they occupy the drainage channel of the Beaver River made by nature, and other parts of their canal where they dig the channel out themselves, they don't claim any superiority of rights in the first over the second, and do not propose to compel all crossings from the mouth of the Beaver to Niles to be raised at the expense of those using them. I want you to understand that I am not opposing the Ohio River Ship Canal, for I believe as Col. Roberts does, that by the time it is completed there will be traffic enough for it and the railroads, that while the railroads may suffer in the beginning, they will gain all they lose by the increase of other traffic, but the opening of that canal would be a great calamity to many. It would not supply a cheaper means of traffic to the men engaged in supplying the lake trade as now carried on, because it would not reach the points from which a great part of the supply is drawn by the railroads, but would transfer a great part of this trade to points on the river and give these a chance to drive the others out of the lake market, like every other forward step it would leave its pathway strewn by many innocent and helpless victims.

An attempt has been made to compare the rights of transportation on the river channels, to the rights of the railway companies on their rights of way and use the care exercised by these railways as to crossings as a justification for the onerous conditions demanded by the river men for all who desire to cross the channel of the navigable rivers. But the railways are obliged to take things as they find them; their right of way is a well defined narrow strip of land 60 feet wide, and must be purchased at great cost, not taken possession of, as with the rivers, without compensation to anyone, and improved, extended and maintained at public expense.

The railways must take care of all other public highways, either raising or lowering them or their own railway, so as to admit of overhead or undergrade crossings, or if that be inadmissable, to provide crossings at grade and endure the delays and loss to their business due to such crossings. But whatever changes are necessary must be made at their own expense, and the other new constructions must be made equally as convenient as were the highways they replace, or as nearly so as can be, and whatever drawbacks result from the existence of these crossings the late comer must bear.

They cannot compel the communities through which their road passes to raise all their overhead crossings after they have been built and in use for years simply because they have found it more economical to use locomotive engines with higher smoke stacks for the handling of their growing traffic. They can not, as our river men think they have the right to do, to first determine what is the most convenient and economical arrangement for their own traffic and then make everybody conform to that without compensation for the cost and damage of doing so. The river men have no such superior rights. If nature had intended to create highways of transportation instead of great drainage channels to carry away the immense seas which covered the valleys of the Ohio and Mississippi and prevent any such accumulation in the future, which she has succeeded in doing in a most admirable way in the river channels as they existed before man touched them, she has most lamentably missed the mark; she would not certainly have left them to be frozen up in winter and dried up in summer, she would

have left out many narrow and crooked places in the channels and many shoals and rapids in the current. In fact, she intended them for drainage channels, and man has interfered to adapt them to use for the conveyance of this traffic.

Now, I have no quarrel with our friends the river men, though they often talk as if they owned the earth, and while they might have some lingering doubt as to their ownership of the whole earth, they seem quite sure that they are the sole and absolute owner of that strip of earth embracing the bed and banks of our navigable rivers, besides having a mortgage on the balance of the United States for the money necessary to open, extend and maintain these as free highways for their use, and that anything that in the least interferes with their full, free and exclusive use and enjoyment of these waters is an iniquitous proceeding. That the railways of the country as well as the large and flourishing cities on the banks of these navigable streams have no rights of crossing which the comparatively small handful of men engaged in the river traffic are bound to respect, but they must, in all matters relating to crossings, bow to the convenience of the river men, and along with the general public, who, as far as their interest in these crossings are concerned, must also bow to the same will, must join in furnishing the money required to keep, extend and improve this system of transportation for the free use of the river men.

If the river men base their claim of priority of right as expressed by Capt. Dravo, on the fact that these waterways antidate by many centuries the advent of the railroad, and therefore have priority of right of way furnished by the generous provision of nature, meaning, as he undoubtedly does, that the waterways are highways of commerce, then I dispute his premises and conclusions.

Nature made these waterways as great drainage channels to carry off the vast body of water that at one time covered the valleys of our rivers, she has maintained them ever since as such channels so as to prevent an accumulation of water, and of this her purpose in making and maintaining these channels she gives us a yearly reminder in the flood of waters she sends through them. She seems to resent the appropriation of these channels by

man for the purpose of transportation by sending down at intervals a great flood, washing away the works of man and returning these channels to the uses she originally intended them. Whatever priority of right the river men can have can only date from their use of these channels as highways of transportation, and not to antidate their rights to the time of its creation as a drainage channel. They cannot claim a superior right to others whom they find in possession of portions of these channels and whose possession and right antidate their occupation and use, but their rights are subservient to them. They must take things as they find them.

This claim of superior right cannot rest on the superior number of people or extent of territory served by the river transportation. It only serves a few people along its channel and a narrow margin of territory along its bank, a very small and insignificant part of the people and territory served by the railways.

The fact that the river transportation can serve this narrow strip of territory and its comparatively small population can give them no such superior right over the railroads as claimed by them, such a right as would enable them to do to the railways what they denounce the railways for doing to their water ways.

Are not the extra cost of the long and high spans and other extra cost, delay and hindrance in the operation of their traffic, over these high crossings obstacles to transportation on the railroads just as narrow spans and low bridges may be obstacles to the transportation on the river? These railways are highways as well as the river channel and have rights of passage over it as well as the right of the river transportation to pass along the channel and under the railway.

If the river men have the right to occupy and alter these natural channels to fit them for their use in passing up and down them, is there any reason why other transportation interests do not have the same right to occupy and use them for the purpose of crossing them?

The right to cross these channels by boats is not less than the right to pass up or down the same by boats. The right to cross is not affected by the angle at which the crossing is made. The right to cross should not be lessened by substituting a permanent bridge for a ferry boat.

The obstruction of a few bridge piers in the river, if they be an obstruction, does not seem to have retarded the growth of the river traffic in the past and probably will not retard it in the future, or if it should retard it somewhat in the future, this will be of but slight consequence when compared with the injury and inconvenience to the vast traffic crossing these rivers consequent upon the raising of these bridges. The traffic passing over these bridges, both highway and railway, is so vastly greater than that passing under them that it would seem very easy to determine whose interest should prevail.

In order to bring before you more clearly what the railways have done for Pittsburgh let me remind you that in 1805 it cost $14 per barrel to transport flour from Pittsburgh to Philadelphia. In 1835 when the State had completed her system of canals and railways between Philadelphia and Pittsburgh it cost $1.12½ for the same service, while at this date the Pennsylvania railroad handles flour in the carloads from Pittsburgh to Philadelphia for 22c per barrel.

We frequently hear the expression that this highway by the river is free to all. That every one who wishes can use is free of charge. This is the theory, but practically it is quite different. You all realize the great difference between theory and practice. This was the theory on which the Commonwealth of Pennsylvania constructed and tried to operate her railways. It was found impossible to allow each person who desired to use the railway, to use it at any time he pleased, with any kind of vehicle and motive power he chose. It was necessary to have rules and regulations as to these matters and to enforce them in order to operate the railways. Now a compliance with the requirements of these rules and regulations involved the investment of considerable capital in a permanent plant, suitable for use on these railways, a much greater outlay than would be justified by a periodical use or a frequent use for small quantities of freight of these railways. It was much cheaper for the ordinary shipper to have the service performed for him by those who had the plant and were regularly and largely engaged in the business. In that way the transportation business on the railways of the State drifted by the operation of the natural laws of business into the hands

of a few transportation firms and companies who were equipped to do the service promptly and cheaply. Now the river traffic, while nominally free to all as was the traffic on the railways, was subject to the same natural laws in its development as were these railways, and the business of transportation by these water ways has developed in the same way so that we now find the business of transportation in these water ways in the hands of a few individuals or corporations equipped to do the service promptly and economically, and that while there is no statute law preventing any one complying with the rules and regulations regarding this traffic from using this highway, yet practically the traffice is conducted by a few and not open to all as that expression is generally understood.

In a speech before the House of Commons of Great Britain in opposition to the granting of a charter to the Liverpool and Manchester Railroad Co., Admiral Sir Isaac Coffin said in part: "I would not consent to see the widows' premises and strawberry beds invaded. Railroad trains would take many hours to perform the journey between Liverpool and Manchester, and in the event the scheme succeeds, what I would like to ask, is what was to be done for all those who had advanced money in making and repairing turnpike roads? What with those who still wished to travel in their own or hired carriages, after the fashion of their forefathers? What was to become of the coachmakers, harnessmakers, coachmasters and coachmen, innkeepers, horse breeders and horse dealers? Was the House aware of the smoke and the noise, the hiss and whirl which locomotive engines, passing at the rate of ten or twelve miles an hour, would occasion? Neither the cattle plowing in the fields, nor grazing in the meadows, would view them without dismay. Iron would be raised in price one hundred per cent., or more probably exhausted altogether. It would be the greatest nuisance, the most complete disturber of quiet and comfort in all parts of the Kingdom that the ingenuity of man could prevent."

Now our good friend, Capt. Dravo, whom we all respect and admire for his loyalty to his first love, the river interests, when he depicts the dire calamity that will result to every home and every industry in the Ohio and Mississippi valleys from the in-

troduction of a few bridge piers in the bed of these rivers, is like the good old English Admiral, perfectly sincere in what he says, but equally mistaken in his prediction.

I think if you have followed me closely you will agree with the statement I made in opening this paper: that to the intelligent, industrious and public spirited citizens of Pittsburgh and Allegheny County should be given the credit of having made Pittsburg what she is. It is not to the turnpike, canal, river, railroad, locomotive or steamboat that the credit is due, but to the inelligent use which her citizens made of them that Pittsburgh owes her present position. These were and are her weapons in the industrial warfare in which she has been and is now engaged, by the skillful use of which she has conquered her adversaries and established her present supremacy. As each nation in actual warfare uses the best armament to be had at the time, and does not hesitate to discard what becomes obsolete to make use of the latest improved arms. So these citizens were quick to use the packhorse, the turnpike, the canal, the river, the steamboat, the railroad and the locomotive as her weapons, discarding the use of each one as it became obsolete and substituting the other as it developed its superiority until now her armament consists of the railroad and the locomotive as her battery of heavy artillery with the steamboat and river as her lighter guns. The locomotive and railroad are the guns of great range reaching from Pittsburgh to the Atlantic and the Pacific, to the Great Lakes and the Gulf of Mexico, their sweep covers every point of the compass, reaches every place in our great land. While the steamboat and river are guns of considerable range they are of less caliber than the railroad, they have no sweep, they can reach but a narrow strip of territory and it is only necessary for the enemy to step to one side to be out of their reach. There are long intervals when they are not available at all for either aggressive or defensive warfare, their printing is either too wet or too dry or the touch hole is frozen shut and they wont go off when you want them and need them the worst, while the railroad and locomotive are always available and ready for use. No matter whether it be wet or dry, hot or cold, day or night, summer or winter, they are ready to pour their broadside into the enemy. There may be at times

too few of them, but no sane general ever dreams of throwing away the guns he has simply because he needs an additional number, he tries by superior generalship, by encouraging his gunners to great exertion to make up in the quality of their work for what he lacks in numbers. As the steamboat and river have become obsolete, as weapons suitable for many phases of this industrial warfare, can they complain that they have been discarded to that extent. The advent of the dynamo and the electric motor may be considered by some as the beginning of a process which will render the steamboat, the river, the locomotive and railroad as obsolete as weapons of this industrial warfare, but I think they will only render these more effective weapons just as the smokeless powder has done for the ordinance of today.

As the Government is spending large sums of money to improve her weapons of warfare, so are the railroad companies expending immense sums in rendering themselves more effective as weapons in the prosecution of this industrial warfare and all this without any investment on the part of those who use the weapons, but they are constantly at the call of the citizens at a small charge for their use, a charge which these citizens make their industrial subjects pay as the Germans collected off of the French the cost of the late war.

I find that this discussion will not be complete without considering the question of the effect of this river and railway coal traffic upon the future of Pittsburgh and Allegheny County. I realize that this will be a difficult question to handle, but I do not see why we should ignore it because of its difficulty, but rather let us attack it courageously, for while I can only present it in a very elementary way, I believe there is sufficient wisdom in this society to give it a full and free discussion and to suggest a fair solution of the difficulty.

The river men and railways are shipping away from Pittsburgh and Allegheny one of its most valuable raw products, the one which is and must continue to be the very foundation of her manufacturing supremacy and greatness, a product the extent of which is fixed and the quantity will never be increased or renewed, but is constantly being diminished at an amazingly increasing rate

each year. These coal fields look inexhaustible to us, but they have a well defined limit, which will be reached much sooner than most of us think. No doubt the vast forests which clothed the hills and valleys of Western Pennsylvania looked just as inexhaustible to the settlers of a hundred years ago as our coal fields look to us today. The exhaustion of these forests looked to those men quite as remote as we consider the exhaustion of our coal fields; one thing is certain, they proceeded to waste and destroy these forests in the same wanton, wasteful, reckless and unnecessary way and without any more regard for posterity than we are doing with the abundant store of fuel, oil, gas and coal that providence has stored in this favored land. In their case they knew that nature, if given time and opportunity, would and could restore these forests, but in our case we know of no process by which these stores of fuel can be renewed when once exhausted.

If some large corporation should become the owner of all, or nearly all, of the farming land in Allegheny County and proceed to dig up all of the productive soil, ship it down the river to enrich some distant desert land merely because they could realize say 50 cents per ton for it more than it cost them to purchase the land and deliver the soil at the point of destination, would not the whole community rise as one man to protest against it and prevent it by force? I do believe our friends the river men would not sanction such a proceeding, even though the soil was shipped by their immaculate system of transportation.

Is not the carrying away of coal to distant ports, to enrich other countries, to enable them to establish industries to compete with the industries of Pittsburgh for the control of markets which she now supplies or might supply but for their competition, a parallel case? Though in case of the coal we would not feel the result as quickly as we would with the loss of arable soil, but the result would finally be the same in both cases, our posterity would suffer if we did not, in the loss of the coal. We would naturally infer that these stores of coal were here for the use of the inhabitants of Allegheny County, but not to be wasted or wantonly destroyed. To use them to promote the welfare of her inhabitants, to build up her industries and support an industrious, happy and

thriving population, would seem to be the proper use to put them, not to be shipped away to distant lands, to build up industries to compete with us.

These coal fields are what has made Pittsburgh what she is. They are what has enabled her citizens to bring her to her present proud position, and they are absolutely necessary to maintenance of that position, and to the growth and increase which she will make in the future, the extent and grandure of which we as little realize as the men of a hundred years ago realized what we see before us today. Why then should we be shipping away the foundation not only of the prosperity of our city, but also of its very existence; shipping it away to build up other communities to enable them to fill markets which we now enjoy and which we should continue to enjoy—to raise up rivals in trade and commerce? That it would be treason to sell arms, ammunition or coal to a nation at war with us we all acknowledge. It would be giving aid and comfort to the enemy of our country to do so, and no one would tolerate such conduct in actual war. But these trade struggles are a species of warfare. Though not accompanied by bloodshed, they are none the less relentlessly prosecuted, with no quarter or truce as the rule and the survival of the fittest as the outcome. Then why should Pittsburgh and Allegheny County give aid and comfort to her industrial enemies by reducing her reserve in fuel in order to enable them to outstrip her in the race for industrial progress, and not husband her resources for the benefit of the Pittsburgh of the future, whose magnificence we are so prone to imagine and depict. This may be considered by some as a very narrow and selfish view to take; that Pittsburgh can afford to be generous. But Pittsburgh and Allegheny County were not created by her enterprising citizens as a huge charity organization, they were not built up by being managed on such a basis for the benefit of a distant and perhaps hostile people, but by strict attention on the part of their citizens to their own business interests and allowing others to look out for themselves they have created this great city. It will not be by giving aid and comfort to her competitors in her struggle to become the workshop of the world that Pittsburgh will be enabled to reach and maintain that position.

To dispose of her coal, the foundation of her present and prospective prosperity, on which rests her chance of supplying the markets of the world with the products of her industries and continuing to do so in the great future, for a comparatively small present profit, would be but disposing of her birthright for a mess of pottage, but without the excuse of starvation, as given of that transaction in the Bible. If any wish to avail themselves of the superior advantages of Pittsburgh and Allegheny County, let them come here and join their fortunes with ours, there is plenty of room, and they are welcome.

To interfere directly to check this depletion of our coal fields, either by river or railroad, would probably be considered by many as unwarranted interference with the freedom of commerce, which they consider should be left free to work out its results. But are we doing this? Is not the lavish expenditure of public funds to prepare and maintain a free highway for this traffic on the river in preference to all other systems of transportation a very great interference with the freedom of commerce? Is there any such superior virtue in this traffic as to justify this preference? Is it of such immense value to the country at large as to require every other transportation interest to give way to it, to sacrifice their interests, not to its necessities, but to its slightest convenience? Is it of such overshadowing importance as to require us to encourage and promote it in every way possible to the injury and inconvenience of the railways and of the great population on each bank of the waterway who seek to cross its channel?

Taking the view that I do as to the depletion of the coal fields of Allegheny County, it may be asked what will Pittsburgh and Allegheny City and their surroundings do when they reach the 1,000,000 mark for Pittsburgh and the 2,000,000 additional for Allegheny County, as suggested by Col. Roberts, and her coal fields practically exhausted, or the difficulty and expense of procuring fuel so enhanced as to rob her of the advantages which she now enjoys from her possession and use of the superior and cheap fuel? As I have already remarked, to attempt to regulate this depletion of our coal fields by law would be too great an interference with freedom of trade, but why not leave this matter to be regulated by the natural laws of commerce? Place this river

highway on the same basis as our railways who are left to take care of themselves, withdraw this artificial support which they now receive, bring them under the same restrictive legislation as the railways, let the river men furnish their own highways or pay the Government a fair compensation for the one furnished by it and you will find this branch of the traffic will, to a great extent, regulate itself.

I have seen it remarked that the most valuable asset of the railways is the scrap heap, indicating that their wonderful progress has resulted largely from their willingness to discard what has become obsolete and substitute better devices as soon as they demonstrate their utility. This has been the history of the public improvements in Pennsylvania in the past, and the policy under which we have realized our present wonderful development in material prosperity. It would seem like a great step backward to compel the raising of each of the bridges between Pittsburgh and Allegheny City and thus introduce such a barrier to communication between them.

There was a time when the Government was the only agent financially strong enough to carry on these internal improvements, but that time has passed. Now let every tub stand on its own bottom, and let the survival of the fittest be the rule. If this river coal traffic is such an inestimable blessing, if it is of such overshadowing importance, if it is of such overpowering magnitude as claimed by its advocates, it certainly should survive the trial and should have no fear of the results. Certainly the private interests which have brought our railroad system to its present magnitude can also develop our waterways if given a chance, and these waterways are able to demonstrate their utility in competition with our railways. This doctrine of the survival of the fittest is hard on the individual man or company, but is the doctrine of almost universal application in the business affairs of the world, and while it seems hard that individuals and companies should suffer as they do under its operation, experience has shown that the Commonwealths and Nations prosper most wonderfully under its operations. It seems hard that the public-spirited men of our State who built 3,000 miles of turnpike which were in use when

the State commenced to build her canals and railways, should lose their investment. That the State, which had expended $40,000,000 in her improved highways should be able to realize by their sale such a small percentage of its expenditures because improved railways, operated by improved locomotives were introduced. But it seems to be the law of progress that these individual losses result in vast gains to the aggregate store of wealth.

Whether the fabulous sums invested in our railways of today is to meet the same fate as the investments in our turnpikes, canals and railways of the past has been a question of great interest to me. Each one of these transformations resulted in great suffering to many, and left a trail of many innocent and helpless victims strewn along its pathway. But what will be the result of the next grand change I shall leave to you to imagine and not risk my reputation as a prophet by attempting to predict.

Some years ago there was quite a widespread discussion and speculation as to what would be the next great invention. The general drift of opinion seemed to be that it would be a means of transportation, and as man had about exhausted that subject on land and water, he must take to the air, and that his next great achievement would be a flying machine.

The great discovery, however, turned out to be the telephone, dynamo and electric motor, all inventions tending to do away with the necessity for transportation instead of facilitating its accomplishment. By the telephone we can talk to our fellows as if face to face though separated by thousands of miles. The dynamo and electric motor enabling power to be generated at one place and distributed by wire for use at many different points as wanted, carrying power to the raw material instead of bringing them to the point of origin of the power. But whatsoever may be the next great invention or the fate of the investments in our railroads, I am willing that my reputation should stand on the propriety of Pittsburgh husbanding her supply of fuel.

Now I think this question of the relative rights on the water ways of the various interests which use and cross them is one that is open to discussion and debate, that it is not such a one sided question as the rivermen would have us believe, and that

much can be said on both sides and that it should be discussed and debated and I bring it forward now in the hope that I may be able to provoke debate and discussion.

I still hold to the old, and, it may be considered by some, the antiquated maxim that the truth should always prevail. Let us then discuss this question fully, frankly, freely and without ill feeling, without fear or favor to any and let the truth prevail.

THE PRESIDENT—We have heard one side of this quqestion very ably discussed, but we have with us tonight a gentleman who has something to say on the other side before the general discussion. It is of course always better to hear both sides of a subject before coming to any conclusions. We have with us Captain Rodgers, well known to almost all of us, and who can speak from a long experience with our local waterways.

CAPTAIN RODGERS—A few weeks ago I received a very brief note from the chairman of your Programme Committee asking me to write a paper on Pittsburgh transportation problems. Had I known that my friend, Mr. Snyder, was going into the subject so extensively I probably would have written a longer paper. Being a river man, you will naturally expect me to make some criticism, perhaps, of Mr. Snyder's paper, but I shall not do so. But since Mr. Snyder has given the history of our waterways, beginning at least as far back as the landing of Columbus, I shall simply ask the privilege of going back to the time of the creation, and request Captain John F. Dravo to answer Mr. Snyder later on.

"IMPROVED WATERWAY NECESSARY FOR COMMERCIAL OUTLET."

BY CAPT. W. B. RODGERS.

This subject presents to my mind a question of the most vital importance to the development of our city. The experience of the last two years has demonstrated beyond contradiction that Pittsburg has reached the zenith of her manufacturing capabilities, unless there is provided additional transportation facilities. Now the question seems to be, How shall we acquire better and greater means of transportation and have it available to public use in the least possible time?

I would call your attention to a means of transportation which is not new, but which seems to be misunderstood by many of our people, although having been employed profitably and conveniently since the time of Noah, viz.,"Transportation by our waterways." It may be said that this manner is not reliable: To some extent this is true, under present conditions, but there is a remedy, and it is being applied in a partial manner at this time. The Ohio river is being improved by a system of dams, now being built by the United States Government, consisting of sixty in number (six of which are nearly completed and six others authorized), necessary to afford slack water between Pittsburg and Cairo. A slight modification of the present plans will be necessary to establish a minimum depth of nine feet of water throughout the year. It is estimated that the cost of completing this system will be fifty million dollars, in addition to what has already been expended. The time required to do the work will not exceed twelve years.

With this improvement of the Ohio and the completion of the Isthmian canal, freights can be moved to the South and to points in the extreme East and West at a much less cost than by any other known way, as water-borne commerce is easily the cheapest method of transportation. This proposition will admit of no argument.

Pittsburg is now transporting coal at a cost of one-third of one mill per ton per mile. Can any railroad system do this? And this cost will be very materially reduced by slack water.

Allow me in this connection to offer a comparison of rates, river and rail, between our city and Cincinnati, classifying the freights. The difference in class rates in favor of river shipping:

	Per ton.	Rail, per 100 lbs.	River, per 100 lbs.
1st Class	$3.20	41	25
2nd Class	3.00	35	22½
3rd Class	1.20	26	20
4th Class	1.00	18	12½
5th Class	.80	15	11
6th Class	.60	12	9

This difference will also apply to many other points, the farther south the greater the difference. The average time saved in delivery by river will be at least fifty per cent. to Cincinnati and points within five hundred miles.

The cost of carrying one ton of freight within the switching limits of Pittsburg by rail is from 60 to 80 cents per ton; the cost of carrying one ton of coal from Pittsburg to New Orleans by water is 66 2-3 cents per ton. The switching limits of Pittsburg do not exceed five miles in distance; the distance from Pittsburg to New Orleans is 2,000 miles. Draw your own conclusions.

Do the above figures not show that with an improved waterway, shipping by water is by far the better method to points where such shipping can be utilized. It is estimated upon good authority that sixteen million tons of freight would be shipped from Pittsburg annually by river, were the improvements completed. Is not this a practical and permanent way of relieving freight congestion? An additional reason might be suggested, that the waterways, when improved, will belong to all the people of the United States, thus relieving them for all time of all apprehension, lest it be dominated by a monopoly. Now, as to its being a greater medium of transportation to the general observer, this should be apparent. I shall only offer a few of its capabilities. When it is improved it will always be on time; it will never stop running and will never be found late. Its freight yards will never be congested, as it will have capacity to hold the accumulated freights of the whole world.

As to what is possible of shipment from Pittsburg by river in one year, with improved facilities, I will not venture to say, but

if our experience of the past can be taken to any extent as a criterion for the future, our ability will be without limit. Pittsburg has shipped five hundred thousand tons of coal by river in twenty-four hours; the *possibilities* seem beyond my conception. Can there be any system of railroads built to equal this out of Pittsburg? If so, at least not in twelve years.

Now, as to the hindrances to navigation about our city, particularly the bridges of the Allegheny river. I had not intended to touch upon this phase of the subject, as it was so well covered by Captains Siebert and Dravo at your October meeting, but on the morning of the 24th ultimo the subject was brought so painfully to my mind by the sinking of our steamer "Margaret" and the loss of life of one man, by reason of collision with the false work and piers of the Pennsylvania Railroad and the Ninth street bridges, that I have thought it proper to say something more on this subject, with the hope that the faults of these bridges may be made so plain to the general public that they will demand a correction whereby the navigation on the Allegheny river may be safe and practicable.

As to the sinking of the "Margaret": She was descending the river on the afore-mentioned day with two flats of stone in tow, at about 10:30 o'clock A. M., broad daylight, stage of water 12 feet and falling, with an experienced crew, the captain and pilot, Samuel V. Carter, having been in our employ for ten years, working about the harbor: The steamer new (one year old), first class in every respect, built at a cost of about $29,000. But notwithstanding the fact that we had taken every precaution, we found it impossible to successfully navigate these bridges for the following reasons: In the first place, insufficient width in the spans, there only being 97 feet not obstructed in the Railroad bridge, the balance being shut up with piling, piling being driven in all the spans, which in addition to the piers create adverse currents both above and below the bridge, making steering of the boat difficult, and as the effect is not the same at all stages of the water, the pilot can not be governed by any fixed rule. Our boat attempted to run the bridge, but collided with the piling and the piers, sinking one flat of stone and partially breaking the other flat loose from the boat, thereby throwing the steamer broadside below the railroad bridge,

completely diverting her from her proper course, and before the boat could be righted she drifted against the pier of the Ninth street bridge, striking about the middle of the boat, breaking her in two, destroying her totally. The distance between the Railroad and Ninth street bridges being only 1,090 feet, and the current running rapidly (eight miles per hour) made the righting of the boat, when once out of shape, an impossibility in the time and space at command.

I have no doubt but that it would be instructive to many of you, were you to make a trip down through these bridges with a good current in the river. You would have an opportunity of seeing a channel way that seems to have come by accident, as there could not be found any set of sane men anywhere that would be willing to stand sponsor for it. The entire lack of alignment of piers constituting channel ways through all these bridges from the Sixteenth Street to the Point bridge is prima facie evidence of complete ignorance of the necessities of navigation. The channel way winding through these piers is as tortuous as a mountain stream, and when coming down through it you can easily imagine that you are shooting the Lachene Rapids with equally as much danger. Is this intelligent engineering? Does this show any effort whatever to safeguard navigation interests? I defy any intelligent man to go and see these conditions and then say that this channel way is practicable? But on the contrary, he will be compelled to say that it is not only impracticable, but criminal, to continue it.

This navigation is so difficult that if by the slightest inaccuracy of aim on the part of the pilot, or if wind or current be unfavorable to any extent, the successful maneuvering of a boat and tow through this crooked channel way, immediately becomes impossible. Then follows collisions with piers, resulting in loss of life and property.

The obstructive features of these bridges must be removed, if for no other reason than to dispel from the minds of men the possible imputation that they were arranged thus to entirely destroy all hope of a commerce on this river, the whole arrangement of these bridges would suggest this motive.

In all candor I would ask those responsible for the mainte-

nance of these impediments in this enlightened age, do you expect to continue them? Is your position fair toward navigators and others interested in the development of the rivers? No, a thousand times no!

The obstructive features of these bridges both in height and width of span must be corrected, as their present condition is abhorrent to every element of common sense.

I therefore submit that our available waterways, unobstructed and improved, offer the greater advantages in solving the transportation problem, present and future, and would best conserve the interests of the whole people.

THE PRESIDENT—Our new director, Mr. Selwyn M. Taylor, was to have written us a paper about the shipment of coal from an engineer's standpoint, but unfortunately he has notified us that he would be compelled to be out of the city, and that he had so much to do before he left that he was unable to prepare this paper in time for our meeting this evening. However, we have something to hear about the congestion of freight traffic which has occurred—once in fifty years, I believe Mr. Snyder said. Mr. Walter C. Herron has something to tell us about the methods of train classification, train delays, causes, remedies, etc., with particular reference to matter of freight congestion.

FREIGHT CONGESTION—TRAIN AND YARD CLASSIFICATION — DELAYS EN ROUTE. CAUSES—REMEDIES.

BY WALTER C. HERRON.

In as brief a manner as possible, I will endeavor to describe the classification of trains, and in order to do this must precede it with yard classification, for that is where the trains are made up and some of the congestion occurs. The yard shifters that work in what is called the yard limit, as for example the Pittsburg yard of Pennsylvania Railroad, extends from Union Station to East Liberty, pick up loaded and empties, bringing them to the nearest classification yard. The agent at Shadyside or East Liberty would give the conductor a card manifest showing initial and number of car, consignor, consignee, loading point, lading, and destination. The conductor dare not move a loaded or empty car without this card. Were he to do so, suspension would be the penalty. This same rule is effective regarding all trains, excepting where they start from a terminal, the manifests are given by the yard master.

When a train arrives at a terminal yard the engine is uncoupled and after dropping the caboose on the cabin track, proceeds to the round house. The cars are then inspected and defects are looked for. It may be that an old wooden gondola or box car whose sills have become weak and the car sags, thus causing sills to crack and break. If the car is going a short distance, it will be marked to nearest shop when empty. If going very far, it is sent to what is known as the bulk track at the transfer to have lading transferred; or if unsafe to move, the work train will transfer the material; the damaged car is then sent to the shop for repairs. The majority of breaks of this nature are due to the cars being handled in heavy trains and the strains longitudinally and laterally upon the sills. These defects are being reduced to a minimum since steel under frames are being adopted. Other defects are looked for, such as broken couplers, broken wheels, broken brasses and cut journals, due to heating; also bent axles, broken journal boxes, etc. Take a train of 30 cars and this means 240

journals to inspect and the packing to renew or stir, or perhaps a brass to insert. The railroad expects three men to a train to do this work. And as more than one train arrives in a yard, a very hurried inspection must be given, as the yard master is after the inspectors, and thus many times a train does not get the attention due it. The yard conductor is given by the yard master what is known as a "cut card," which shows how the cars are to be drilled or shifted. A "gunnie" (nick-name given to brakemen, because cars are "shot" down the track) chalk marks the cars for various tracks in the classification yard, such as hay, iron, coke and coal, household goods, etc. In yards where "poling tracks" are use, that is, a parallel track to one which cars are upon ready for drilling, a man mounted on the poling car which is coupled to the engine, swings the pole against car or cars, and thus they are given a start and run to the track or tracks for which they are intended, by momentum and gravity. A switchman is stationed at each of these tracks, which are known as ladder, due to the side tracks diverging from the main line, and upon a signal from the brakeman, throws the switch. Sometimes a brakeman does not correctly measure the distance before applying brakes, "running in" to other cars on same track, damaging them to such an extent that it is necessary to shop same. A broken end sill, coupler or stoved end is the usual result of such proceedings. This, of course, means a delay to loaded cars, and they are probably those that "someone" is keeping the wires hot tracing. It is often five, six and eight hours before the cars are given yard movement, the shifters being busy elsewhere.

In case it is a P. G. train (perishable goods) the car damaged is sent to the shop with a shifter, and it stays there until the car is repaired, providing lading does not have to be transferred, and even then the car is hurried to transfer and lading placed in another car quickly as possible. Everybody is on the "jump" until the car is gone. These P. G. trains run through solid, being made up at some point East or West, New York or Chicago.

The operation of drilling cars goes on until they are all classified. The conductor and crew that are to take certain trains get them in position to start out. All cars with structural iron or steel are coupled together; the same is true of cars loaded with

hay, grain, and mixed merchandise, these being generally placed in the front. Explosives are always hauled in the rear, if at all possible. The tonnage rating of the engines is considered, which is about the same on the respective divisions, and they are given cars accordingly. Before starting, the conductor notes in his "duplicate record book," commencing at the tender—the initial, number, class of each car, its number of wheels, as it stands in the train, also the number of the cabin, or such car as may be used therefor. The mark X is placed after all loaded cars, and — after empties. If a car is loaded and unloaded en route, separate entries are necessary, as if each movement was made by a different car. In the freight equipment the class of cars is designated thus: B for Box, R for Refrigerator, G, Gondola; H, Hopper Gondola; F, Flat; K, Coke; D, Coal Dump; L, Lime; T, Tank; C, Cabin. The maintenance of way equipment thus: M. C., Cabin; T. B., Tool and Block; S. P., Snow Plow; Dk., Derrick; S. W., Stone and Wood; G. D., Gravel and Dump. All sidings are numbered, starting with No. 1 at Broad street, Philadelphia, and the numbers getting higher westward.

The siding number is given at starting point, and any cars left en route, entry is so made in record. At the division terminal, the report is forwarded to the car record office. In this office there are about 350 clerks, and the record of so many cars is assigned to each. The movement of the cars are thus entered, and in the event of wishing to know where a certain car is, what train hauled it, by reference to this record the information is easily obtained. The trace sheet sent to the offices of the railroad company show, for instance, P. R. car 89753, Extra 1763 West, Condr. Jones, Altoona 1-9 loaded, Johnstown 1-9 loaded, Derry 1-15 empty, Wall, 1-18 loaded, 1-19 Car Shops in 1-19 Car Shops out.

The train being ready to start out on the road, the train pulls up to the yard master's office, or if at extreme end of yard, telephones Extra 1579, East, Condr. Williams, is ready with 25 cars. This train number is taken from the engine, coupled to the train. Assistant or pushers, not given. The yard master then wires the chief train despatcher and receives orders for the train, one for the conductor and a duplicate for engineman, both copies to be signed by them in presence of the operator. Thus the train starts

and is reported by telegraph to the next block station or signal tower, and when same passes that point, it is reported back. Thus the train despatcher has a record on his train sheet of all trains on the road, and can easily wire orders where they shall pass certain other trains. In case a train is not filled out to proper tonnage, the yard master at next yard is notified by telegraph dispatcher, and knowing when "she" is due, he stops it and fills in the requisite number of cars.

The train is now en route, and we will consider some of the delays. The principal one and most exasperating is due to hot boxes. A conductor may worry along for miles, and the retarding of his train blocks those following, that is if he can get through to a yard, where the car can be cut out. If not, he must drill car out at first siding. This car may be in the center of the train, but out it must come. While doing this work all the other trains back of it are held up. If it is a loaded or even empty, a telegram is sent to the superintendent's office, who in turn wires the car inspector. An examination may prove that only a new brass is needed, or many times, as it has been, the journals are cut, necessitating the changing of the truck or replacing new wheels. This at least means a delay of five to seven hours. Sometimes a journal burns off, letting the car down and wrecking the train, or five or six cars of it, necessitating the calling out of the wreck train, and in the meantime tying up traffic. This hot journal question is vexatious, but the trouble can be traced to robbing the axle or journal box of packing and inattention on the part of railroad employes. Naturally the journals get hot. Cars loaded with coal, coke, stone and sand are in the lead in this matter. These cars are in on sidings at coal mines, coke ovens and stone quarries, and the journal boxes and waste get full of dirt and grit. No inspectors are provided at these coal mines, and if the employes of the coal concerns want to start a fire, they just rob the journal box. The railroad company has not and, in my judgment, never had a sufficient inspection force.

Long hours for train crews and the enginemen is another cause. Sometimes they are five days making a round trip. They become sleepy and often run into trains ahead of them, wrecking both and tying up the traffic for hours. In some cases they in-

dulge in "liquid refreshments of a harmless nature" to stimulate them, and do not know whether they are going or coming back, and other crews have to be sent out to bring in the trains. Carelessness and disobeying orders also cause trouble. Nice quick stops at water tanks, with a jam for a result. Making flying switches and coupling up too hard. There are wrecks on the railroads every day that are only known to the railroad company. Much freight is damaged, freight and cars destroyed and lading lost. Sometimes the Company seizes the lading for company use, especially coal. They pay for it, but that is not helping the consignee.

The shortage of cars, due to so many being out of service, and of engines, being crippled and in the shops, is another cause. It is next to impossible to get a good all around roundhouse man. Those employed in the erecting shops of our locomotive works are specialists, and cannot work on any part of an engine. It would be advisable to have men learn the all around work. The general run of machinists do not know how to handle locomotive work, and thus the repairs are tied up. An engine is given enough attention to get her out on the road, and if it gets "lame" en route, then it "lays down," and ties up all following trains. Leaky fireboxes, flue sheets, broken stay bolts, are among some of the defects. Also wheezy air pumps, lame valves, etc. True, the railroad has more than it can handle, but nevertheless they were caught napping. When times were dull, and material and labor cheap, they could have employed their men building engines and cars and then when the rush came would have been prepared. Some of the millions being spent for improving the physical condition of the road could have been used for the benefit of the manufacturers. They want the trade, and should supply the cars. As it is now, material and labor is high and the cost is as much more, with no results. True, they thought it unwise to invest so much money in equipment, yet the large machine shops, with the thousands of dollars' worth of tools, were idle, and the machines did not earn the interest on the money invested. Thus the expenses are increased.

The only way these delays en route can be remedied is to employ more car inspectors and efficient operative employes. The

shops should have good all round mechanics, crews should not be so long on the road, and more equipment should be forthcoming.

In many of the towers up in the mountains young ladies are employed, many of them are on duty at night. As a rule they are efficient and reliable. In all of the towers, the company has students, and when the time comes they are given charge of a tower. Accidents sometimes occur through misplaced orders.

THE PRESIDENT—We have heard a paper telling us very clearly and concisely some of the reasons why we have this congestion, followed up with a few pointers for the railroad people. Before opening the general discussion, I have been asked by one of our ex-presidents, Colonel Roberts, to permit him to say a word or two.

COLONEL ROBERTS—I had the privilege of looking over a copy of Mr. Snyder's paper today, and have prepared only a few remarks, as the time was so late.

REMARKS BY COL. THOMAS P. ROBERTS.

Remarks by Thomas P. Roberts, member of the Society.

Notwithstanding the fact that Mr. Snyder considers our rivers to be antiquated and comparatively worthless, means for transportation being in fact little better than sewers, we have at our own doors an illustration of their usefulness in the case of the Monongahela, even when improved upon a model more than 60 years old, providing for small locks and depths of only six feet. On this same Monongahela river last year more than 9,800,000 tons of freight were moved.

Mr. Snyder is not so well informed in his modern as in his ancient history of Pittsburg's river traffic, thus he would have his readers infer that Pittsburg derives but little advantage from the improvements so far made in the rivers of this vicinty. He says (p. 23): "After passing into the harbor of Pittsburg, the great coal tonnage is divided into two parts, the one, a very small part, being distributed to the various consumers along the river front of Pittsburg and Allegheny City, the remainder held in great fleets to be shipped down the Ohio river." The facts are, that of the 10,000,000 tons of freight annually moved in our harbor, not quite one-third is shipped down the Ohio. One establish-

ment in this city which until a few years ago received its fuel supplies by railroad, finding that it could save two-thirds the cost of transportation, changed over to the river, built its own tow boats and barges and is now receiving 38,000 tons of coal weekly by river, or nearly 2,000,000 tons annually. This establishment has hoists in use unloading from boats 600 tons of coal per hour. It received its fuel regularly by boat last winter when there were 12 inches of ice on the pools through which the boats were moved.

It is thus shown that where there is traffic enough to warrant it, the boats can be depended upon to keep the river open for navigation during the coldest winters. The large iron and steel company here referred to joined its name with other manufacturers interested in keeping open the river connection between the mills on the Allegheny and on the Monongahela, and favored the raising of the bridges on the Allegheny river for this purpose.

I happen to know the fact that last winter the same firm, fearing that the ice would close the river, applied to the railroads for a coal supply, but not a car could be given them owing to the freight congestion. Other large firms are also resorting more to the river, and it can be said, without being successfully controverted, that it is not within the means of the railway companies to meet the large and increasing demands of these great establishments for fuel. Instead of it being accounted a loss of traffic to the railroads, the assistance rendered by the river to these mills should be considered an advantage, enabling them to use their cars for better paying traffic.

That the commerce of the Ohio river would grow rapidly if it were improved by means of dams with locks, admits of no argument; at present, however, it is doing about all that can be expected, considering the shortness and the irregularity of the periods that it can be navigated.

Mr. Snyder is apparently not aware of the fact that miscellaneous shipments, such as glass and iron, can be shipped by the Cincinnati packets from Pittsburg to independent railroad transfer points below Cincinnati and thence transferred to railroads and sent to Chicago and Milwaukee for less than all rail direct. And that for Denver and Los Angeles shipments, goods are sent by these boats for less than half the rail charges. With the de-

velopment of the beneficent principle of "community interest," however, the independent railroads in the West are being bought out, so that the Denver, Los Angeles and Milwaukee merchants will shortly find the advantage of the Ohio river packets sealed to them. It is certainly true that the railroad will soon have its competition with river rates eliminated from all points away from the immediate margin of the river.

Mr. Snyder may regard it as a calamity for a town nowadays to be located on a river where the United States declares its navigation to be free; there remain, however, many manufacturers who will give from $2,000 to $5,000 per acre for river front property, whereas they could buy similar acreage along some of the trunk line roads away from the river for one-tenth the same.

Many railroad engineers deride the canals built by Pennsylvania 60 years ago, and which were constructed over mountains, requiring a ridiculous number of locks. Those canals, it should be remembered, were only four feet deep, and were never enlarged.

New York, which took better care of its canals and was also fortunate in having them on better natural routes than those built by Pennsylvania, is today proposing to expend $80,000,000 on their enlargement to meet modern conditions. New York is proposing to do this for the betterment of a commerce which would not nearly equal that of Pittsburg's proposed canal to the lakes, which can certainly be built for less than $35,000,000. If it be bad policy for our people to sell any of their coal to strangers, seeing that we have not more than enough to last six or eight hundred years, what must we think of the improvidence of the Western farmers who, in less than 50 years raising and selling wheat will have robbed their land of the chief elements of its fertility. This problem is presented seriously by Mr. Snyder and calls for consideration.

The attempts to deride and cripple the movement which has been, and is being, made by the United States for the improvement of our natural waterways are neither wise nor patriotic. Our people want every possible means of transportation enlarged and improved to meet the phenomenal development of the country. Our rivers being a network—and interstate system of channels—

it is becoming that the National Government, and not private corporations, should improve and operate them. There is not the slightest inclination or desire on the part of the friends of the rivers to throw unreasonable restrictions in the way of the railroads, but when it comes to crossing the streams with bridges, it is right for the government to say, "These are the free highways of the people, being improved with the people's money, therefore, do them no injury which can be avoided by a reasonable expenditure of means." One single illy devised bridge structure over a navigable stream may for all time debar the people over an extensive area from partaking of the benefits of a system of improved waterway below said bridge.

THE PRESIDENT—The little paper you have just heard was written after its author had read Mr. Snyder's paper, as Colonel Roberts acknowledges. The custom is to have a little discussion and then give the author an opportunity in rebuttal, but of course he must be under fire, and I think among the first shots will be one from one of our gunboats. Captain Sibert, what have you to say?

CAPTAIN SIBERT—I saw Mr. Snyder's paper last night also, and have prepared just a few remarks, but there is hardly time to read them.

DISCUSSION OF PAPER PRESENTED BY MR. ANTES SNYDER BY CAPT. WM. L. SIBERT.

"Oh wad some power the giftie gie us,
To see oursels as ithers see us!"

It is thought that the man has at last been discovered who, on returning from a pilgrimage over the world, stated that the coincidence that impressed him most and was the most inexplicable was the fact that all large rivers flowed by large cities! The psychological condition of such a mind is in keeping with a mind that fully justifies the retention in Western Pennsylvania of the great coal wealth of the country concentrated in that section, and at the same time take from Michigan all of her iron ore, and from Maryland her lime. Taking everything from everybody and giving nothing in return, it matters not how cold the winter or how dire the distress of the people, for fear that some manufactories may be developed elsewhere. In keeping with the mind that

reaches the conclusion that our rivers were intended by nature for great drainage channels only and that it was never intended that they should be natural highways of traffic, or they would have been created of permanent depth, been free from floods and chances of freezing.

One could argue from the same premises that nature never intended the construction of railroads in this section of the country since the roadbeds were not created by nature, and that railroads were never intended to cross rivers, since bridges are necessary, otherwise nature would have provided the bridges.

This peculiar condition of mind is still further illustrated in the argument to prove that the coal in the Allegheny Valley will never be developed by water transportation, because of the superior coal of the Monongahela Valley, knowing at the same time that the railroads are hauling coal mined in the Allegheny Valley which is in the immediate proximity of the Monongahela; that coal is being excavated from the mines of the Allegheny at a rate three times as great as it can be hauled away by the railroads, and presumably at a profit. I have in my possession a copy of a letter from a superintendent of the Pennsylvania Railroad to a mine operator on the Allegheny river, in which the statement is made that they had been unable to furnish more than 33 1-3 per cent. of the cars demanded by the various mines along the Allegheny river. The Pittsburg & Buffalo Co. is now mining 500 tons of coal per day, and by this time next year will mine 1,500 tons. This company says that it has now 250,000 tons of freight per year suitable for river shipment, and would so ship were the river available.

It is very difficult to argue against the reasoning in Mr. Snyder's paper. There are a few salient points, however, that should be borne in mind in the consideration of this paper, of which the first is the fact that the bridges on the Ohio river are now of sufficient height. Some of those earliest constructed have not, however, a sufficient width of span, but the present status of bridge engineering makes it a more easy task now to increase the spans of these bridges to their proper width than it was to construct the original narrow span. Second, the bridges over the Monongahela river, at least as far up as Monongahela City, are admitted to be

of sufficient height for the needs of commerce, from which it appears that the bridges which, according to Mr. Snyder's statement, comprise those on the Ohio, Mississippi, Monongahela and Allegheny rivers, are really reduced to those in Pittsburg harbor from Forty-third street to the mouth of the Allegheny river. Of these nine bridges, three are old wooden structures that should be rebuilt, and two others are under agreement to raise whenever the Government of the United States says so. So the question of bridges as stated by Mr. Snyder as comprising all those of the Monongahela, Allegheny, Ohio and Mississippi rivers, reduces itself in reality to four or five bridges crossing the harbor of Pittsburg in the Allegheny river.

The Congress of the United States in its wisdom has, since 1862, considered that a clear height of 90 feet above low water was essential to the full use of the Ohio river. The condition presented, therefore, is that a navigation requiring such a height comes, on entering a portion of the most important harbor connected with the Ohio river, in contact with bridges having a clear height above pool water of from $27\frac{1}{2}$ to 35 feet.

It can be demonstrated that it is thoroughly practicable and feasible to raise the bridges referred to, giving on the highway bridges grades not to exceed four to four and one-half per cent., and giving on the railroad bridges grades not exceeding those on the same lines in the near vicinity. It is admitted that in a system of transportation designed for a plane, the injection of a grade of four to four and one-half per cent. would cause a serious interference, but in a city such as Pittsburg, a city in which every line of street cars passes over greater grades, and many of them; in which wagon traffic continually and at many points in its route passes over greater grades that the injection of one more little hill into the system that has many bigger ones would not disturb the equilibrium. It is furthermore thought that property owners who will not raise their property above flood level and cities that established street grades as much as six feet below flood level, have little right to complain of grades on bridges starting from such streets and crossing one of the most important harbors in the United States.

The City of Chicago requires all the bridges across the Chi-

cago river to give sufficient head room for the largest lake steamers. This is done by rolling bridges. The City of New York, whose water-borne commerce is about the same as Pittsburg, has only one bridge across her harbor, and that is, I believe, about 135 feet above water, and the Pennsylvania Railroad is now tunneling under the North river for an entrance into the city.

It is admitted that unimproved waterways and other intermittent lines of communication are not such as are demanded by modern commerce, but it is contended that where waterways can be relied upon for continuous service for specified lengths of time that they are still the cheapest method of transportation for certain kinds of freight. The original limiting depths of the Great Lakes and the connecting waters thereof were from 9 to 11 feet. The Government of the United States increased this depth, first to 16, then 18 and then 20 feet, constructing the great locks at the St. Mary's Falls canal to pass from Lake Superior to St. Mary's river, and although this line of transportation is available only about seven months in the year, it has so cheapened the transportation of wheat from the great Northwest and of iron ore from the Superior region, that practically every line of railway has its line of steamers on the lakes. Who are the river men to whom this system of transportation belongs? Our navigable waters belong to all our people. Any man can use them. They can never be "Morganized."

The benefits that accrue to the people of this country from their improved waterways are not always measured by the absolute amount of freight handled on the rivers in question, but by the reduced rates for freight carried by the railroads caused by the water competition. And when we remember that the ultimate prosperity of our country must depend upon the prosperity of the common people, especially the farmers, and that the prosperity of this part of our people must depend upon their ability to compete in the markets with their products, we see that the question of cheap transportation will ultimately determine the question of national supremacy in the trade world. It was cheap transportation in France, brought about by improved waterways, that enabled that nation to pay the heavy indemnity imposed upon her by Germany after the Franco-Prussian war. When our surplus products must

seek foreign markets, cheap transportation to tide water will determine the question whether or not our goods can be sold as cheap or cheaper than those made by other countries.

This country needs all of its systems of transportation. It needs its railroads, because the railroads must reach a greater number of people than the rivers, but if the rivers take their proportional share of the commerce in and along their borders, and to points connected therewith by competing railways, the other railroads will then be able to more efficiently perform the duty of transportation to points not on the river.

It should be borne in mind in this case that this is a broad question that should be solved on broad grounds, and that a clear height of 50 feet for the bridges in the Allegheny river from Sixth street up is not as much as is ordinarily demanded in other sections of the country, and that the development of the Allegheny Valley and the connection of that valley, including a portion of the Pittsburg harbor, with the Ohio river, should not be stopped by mistakes made by highway and railway companies in the original construction of their bridges, or mistakes made by the Cities of Allegheny and Pittsburg in originally establishing street grades below the flood lines. The development of this valley will mean a marked increase in business for railroads. "Live and let live" should be our motto.

As I stated in a paper previously read before this Society, I know of no one thing that would relieve the freight congestion more than the conversion of Davis Island dam into a fixed dam and the raising of the bridges in the Allegheny river, thus enabling the many manufacturing plants in and about Pittsburg to obtain their fuel and to transport their material from one mill to another by water. It can be done more cheaply and more quickly, thus enabling the railroads to haul the raw material to Pittsburg and the finished products away, and supply our people with that great

THE PRESIDENT—Captain Henderson, what have you to say on this subject?

CAPTAIN HENDERSON—I shall be glad at some future time to prepare a paper for this Society. I did not, however, prepare one for tonight and in fact did not come here with the intention of speaking on the subject.

THE PRESIDENT—Mr. Lyons, have you anything to say on this subject?

MR. LYONS—I have nothing special. A few questions came to my mind while Colonel Roberts was reading his paper, and I would like to ask him in regard to the transportation down the river. He made one statement about the great number of dams to be put in the Ohio river. A few years ago the question was raised as to the span length that was imposed for all bridges built over the Ohio in the future, and also with a view to providing for increasing the spans in case of the rebuilding of old bridges. Now, with reference to these large coal fleets. If we get 60 dams in the river from here to Cairo, the river men will certainly have to break these tows up in passing through the locks. Will this not mean that the river men must rearrange their methods of shipment, and if such is the case, what is the necessity for having bridges with spans 800 feet long. It seems to me that the loss in time in passing these locks with big tows would be far greater than the advantage derived from having bridge spans long enough to let these large boats through.

CAPTAIN RODGERS—I would not expect any greater loss of time with our present size of tow boats than is occasioned now from other causes. The loss of time in going through 60 such locks with tows of the present size in addition to the steamboat, will certainly not be as great as is now caused by laying up.

THE PRESIDENT—The subject is now open for general discussion. Is there anybody else who desires to express an opinion.

MR. SCOTT—We know that history repeats itself. Large events move in cycles, prosperity comes and goes, and ideas and mental attitudes change. One of the most interesting things Mr. Snyder has pointed out is the attitude some fifty years ago of the people of Pittsburg and Allegheny towards railroads and railroad bridges at that time, and how both thought that the hack drivers and the dray drivers, who profited so much in the transfer of passengers and baggage, of so great importance that they opposed the construction of a bridge. I have been trying to discover any essential particular in which the attitude or sentiment which exists at the present time against the raising of the bridges differs in any important particular from that exhibited

in the earlier times. Is it not a case of hack driver in both instances?

MR. SNYDER—I introduced this subject in order to bring out this discussion. I am very much pleased that it has been so well discussed, and I am obliged to the river men for coming and taking part in it. I want this subject to go out in our transactions with a good discussion. My ideas are of course quite different from those of some of the gentlemen present. They think Pittsburg will reach her zenith of power by increasing the facilities for shipping our coal away. I think she will go down by that process.

CAPTAIN RODGERS—It was not that she would reach her zenith of power on account of the lack of facilities for shipping coal only, but other products as well.

MR. SNYDER—Still I do not think we can afford to haul coal away indiscriminately for this reason. This improvement of Pittsburg is not going on increasing and increasing until you burn the last ton of coal. It will not be a great many years until Pittsburg will have lost her advantage because of the increased cost of production of coal within a limited radius. I do not mean that we can reduce in a few months the fabric of industrial interests which it has taken 60 years to build up, but there will be a gradual decrease in her prosperity.

CAPTAIN RODGERS—That question, however, will not bother you or I even unto the tenth generation.

MR. SNYDER—You are Captain, somewhat like the Irish member of Parliament in the matter of the disposition of certain surplus funds which at one time existed in the Government treasury. One party wanted to give this money to the king; another party to spend it for internal improvements, picturing the benefits that would accrue to posterity. "But," said this Irish member, "what did posterity ever do for us?" I still think, however, we should take posterity into consideration after all.

MR. HERRON—Has the Pennsylvania Railroad ever hauled any coal away from Pittsburg? I do not share with Captain Sibert his anxiety as to the state of my mind; that will take care of itself. It is the quality of my reasoning which concerns me and which Captain Sibert says is very difficult to argue against. Railways are of comparatively very recent construction, and it is

only since their introduction that large inland cities have been possible. Transportation being essential to the existence of cities, it was necessary before the advent of the railways to locate such communities on the banks of rivers. While it may not be altruistic to take all you can get and give as little as you can in return, it is the way of the world and the universal rule of business competition, and Pittsburg must suffer as she departs from that rule. The traffic from the Allegheny Valley by railways is large and will continue to increase and develop even if the bridges are raised, because this railroad traffic is to points not reached by the river route; my point is that any increase of traffic from the Allegheny Valley resulting from the raising of the bridges must be gained in competition with the Monongahela Valley.

The admirable system of waterways of France was constructed long before the introduction of railways, and I believe that had the development of her transportation system been delayed until railways had been developed they would have greatly modified the development of that system. The saving in cost of transportation by river over that by railway is not fairly shown by the figures given. They show the portion of the cost of transportation by river which the transporter pays and leaves out the large share of the cost of transportation which is borne by the general public and paid for by a tax expended in the construction and maintenance of a highway free to the transporter.

Mr. Snyder—Of course, the railroads are doing the same thing as the river steamboat men. I am not speaking this evening as a railroad man, but simply as a citizen of Pittsburg.

Member—It seems to me that the natural advantages which have brought a great number of citizens of Pittsburg to her during their life time are really the determining factors. If at any time the natural advantages of Pittsburg begin to wane her citizens will go where these advantages exist. It therefore seems to me that it is the people and not the locality that should be considered.

The President—That brings to my mind the city of Bruges, in Belgium. This city was at one time one of the foremost cities in Europe, having a population of nearly 200,000. At that time they had a clear waterway to the ocean, and vessels of the largest class could come up to Bruges. However, they allowed this waterway

to fill up gradually, so that finally ocean-going vessels could not pass up the channel, and the waterway fell into disuse. The result was that Bruges became a dead city. If you go there now you will find elegant houses, churches, and buildings of every description, but it is like a city deserted, with grass growing up in the streets. Barely 18,000 people live there today. Now, after the lapse of over two hundred years, it is an impressive example of a once prosperous and flourishing city which has lost its prestige on account of lack of water transportation.

We have listened to Mr. Snyder's paper, which is a very excellent historical one that will be a credit to our proceedings, and one that we will sit down and read later with a very great deal of pleasure, and be glad to add it to our library collection. We have had short papers from Colonel Roberts, Captain Rodgers and Captain Sibert which were strictly to the point, and we have had a very good paper on railroad freight congestion. Such papers as these are exactly what we want. If a man has an opinion, let him say it and stand right by it, and speak up for it; and when anyone gets knocked down by a better argument, the only thing to do is to acknowledge it gracefully. We are not here to absolutely decide these questions about waterways and railroads and bridges, but simply to discuss them. I am sure it has been a great pleasure to all of us to have such a meeting. This meeting is my first one as a regular presiding officer, and it has been with great interest that I listened to that long list of new members. These new applications I think are largely due to Mr. Scott's work last year, when this work was started, and we want to keep it up. As Mr. Swenson says, "One thousand new members for 1903"! We have made a good start, and desire everyone to do their best to help things along.

MEMBER—I would like to ask Captain Rodgers one question. It seems to me that the river men need not build their boats as high as they do now. Why not build the stacks lower and avoid the necessity of raising the bridges at all.

CAPTAIN RODGERS—The height of the stack does not enter into the question at all. There are a number of reasons for the present height of our boats, and also a number of reasons why they should be higher. As I stated, the height of the stack does not

enter into the question, and the pilot house to some extent only. However, the man who runs the boat is guided by marks both ahead of his boat and behind it, particularly in running bridge piers, and he must have his boat on these marks. The pilot house of course, therefore, must have some elevation. Another reason is that we cannot build the boats out wider on account of the locks and must therefore build up. Then again, accommodations must be provided for the crew. Then the Government requires engines and boilers to be according to certain specifications and qualifications. There are other reasons for asking for higher bridges, so that we can get higher boats and larger boilers and larger engines. Boats now plying on the Monongahela cannot get up the Allegheny because they cannot get under the bridges.

THE PRESIDENT—There are two points before we close. One is that there has been some complaint about failure of notices, transactions, etc., etc., to reach certain members. We have here an addressograph which is supposed to have the name of every member upon it. It is possible that this machine might skip a number. We cannot account in any other way for failure to get our publications. The secretary would consider it a favor to him if members will advise him promptly by postal card or otherwise that they have failed to receive printed matter of the Society.

The other point is this: Mr. Ridinger informs me that we have perhaps 150 keys to the front door and that it has been customary in the past to charge $1.00 for each key. But I will take it upon myself to say that these keys may be had at very much less. If any member wants one they can have it.

A vote of thanks was passed for papers read.

Adjourned.

C. W. RIDINGER,
Secretary.



CHESTER B. ALBREE.

President Engineers Society of Western Pennsylvania for 1903.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and thirty-second regular meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture Room of the Society's House, 410 Penn Avenue, Pittsburg, Penna., Tuesday evening, Feb. 17, 1903, at 8:30 o'clock. The President, Mr. C. B. Albree in the chair, and ninety-three members and visitors present.

The minutes of the preceeding meeting were read and approved.

The Board of Directors reported that they had passed favorably on the following applications for membership and present same to the Society for action.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY
ALFRED ACKLIN,	Mechanical Engineer, Heyl & Patterson, h., 828 Adelaide Street, Pittsburg, Pa.	F. V. McMullen, H. A. Otto, E. J. Mason.
HARVEY ALLEN,	Draughtsman and Checker in Drawing Room, Pressed Steel Car Co., Allegheny. h., 3909 Perrysville Avenue, Allegheny, Pa.	M. C. Blest, F. V. McMullen, E. J. Mason.
JAS. B. ANDERSON,	Vice-Pres. and Superintendent Concrete Construction Co. 6812 Frankstown Avenue, Pittsburg, Pa.	W. G. Wilkins, W. M. Judd, C. W. Ridinger.
CHAS. D. BADEAU,	Manager Pittsburgh Office, Cutler-Hammer Mfg. Co. 319 Frick Building, Pittsburg, Pa.	J. Duncan, C. F. Scott. H. P. Davis.
HARRY BAINBRIDGE,	Supt. Structural Dept. Jones & Laughlins Steel Co., Pittsburg, Pa.	F. S. Slocum, T. O'C. Jones, C. W. Ridinger.
CHAS. E. BARTEAU,	Draughtsman, with W. G. Wilkins. h., 663 College Avenue, Pittsburg, Pa.	J. R. Elliott, W. M. Judd, W. G. Wilkins.

JOHN C. BOLE, - Iron and Steel Merchant, - { C. B. Albree, R. Albree, C. W. Ridinger.
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HAROLD L. BOLTON, - Draughtsman, - { S. B. Ely, F. M. Kennedy, H. Anderson.
American Sheet Steel Co.,
Vandergrift Building, Pittsburg, Pa.

DAVID H. BOYD, - Transitman, - { A. Smith, J. M. Camp, C. F. Scott.
Bureau Filtration, City of Pitts. Pa.
Penn and Murtland Avenues, Pittsburg, Pa.

HOWARD L. BROWN, Ass't Eng. of Construction, { A. E. Wells, F. Engstrom, P. Brynn.
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FRANK L. IRWIN, Mechanical Draughtsman, { G. Griscom, Jr., C. B. Albree, R. Albree.
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h., 224 Jackson Street, Allegheny, Pa.

HENRY T. IRWIN, - Treasurer - { C. B. Albree, G. Griscom, Jr. R. Albree.
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h , 1636 Fifth Avenue, Pittsburg, Pa.

JOHN H. JONES, Engaged in Coal and Manufacturing Business. (A. Dempster, C. B. Albree, C. W. Ridinger.)
h., 437 Rebecca Street, Pittsburg, Pa.

LUTHER L. KNOX, Member firm of Grove & Knox, of Consulting Engineers. (R. McKinney, S. M. Taylor, H. M. Wilson.)
P. O Box 341, Pittsburg, Pa.

J. F. KUNTZ. - - Architect, - - and Assistant with Wm. G. Wilkins. (W. G. Wilkins, W. M. Judd, V. Beutner.)

HOYT D. LUFKIN, Production Department, Westinghouse Electric & Mfg. Co. (W. M. Judd, C. F. Scott, W. G. Wilkins.)
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FRANK McCUNE, Geueral Superintendent, of the Monongahela Connecting Ry. Co. (F. S. Slocum, M. J. Dowling, D. S. Rolfe.)
h., Sheridan, Allegheny Co., Pa.

J. MACENULTY, Engineer of Construction, Pressed Steel Car Co., Pittsburg, Pa. (M. C. Blest, F. V. McMullin, E. J. Mason.)
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JOHN B. McINTYRE, - Chief Engineer, - St. Clair Terminal R. R. Pittsburg, Pa. (C. B. Albree, T. P. Roberts, A. C. Gould.)

GEO. H. NEELSON, - General Manager, - Braeburn Steel Co. (Wm. Metcalf, G. T. Barnsley, C. B. Albree.)
h., Arnold, Pa.

DAVID K. ORR, - Civil Engineer, - P. & L. E. R. R. (E. F. Wendt, R. M. Pearce, C. W. Ridinger.)
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{M. Knowles, M. A. Tenney, C. W. Ridinger.}

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{E. F. Wendt, R. M. Pearce. J. A. Atwood.}

A. C. ROGERS, Snperintendent of Construction,
for Pittsburg District Stoker Business,
with Westinghouse, Church, Kerr & Co. h., Oakmont, Pa.
{J. P. Young, W. Bradford, Edwin Yawger.}

ALEXANDER B. SHEPHERD, Superintendent,
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{C. B. Albree, R Albree. C. W. Ridinger.}

CHAS. SIEBERT, Mechanical Engineer,
American Steel Hoop Co.
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{F. L. White, H. J. Glaubitz, A. N. Smith.}

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h , 129 Forty- second Street, Pittsburg, Pa.
{A. E. Wells, F. Engstrom, P. Brynn.}

WM. L. SEIBERT, In charge the Improvement of the Rivers in and about Pittsburg, Pa., and a Captain of Engineers, U. S. Survey. 409 P. O. Building, Pittsburg, Pa. — C. F. Scott, T. P. Roberts, H. C. Gould.

CHAS. V. SLOCUM, - President, - Keystone Car Wheel Co. 1209 Park Building, Pittsburg, Pa. — C. G. Hussey, C. B. Albree, S. B. Ely.

JOHN STUEBER, - Foreman, - American Bridge Co. h., 125 Fountain Street, Allegheny, Pa. — A. E. Wells, F. Engstrom, P. Brynn.

J E. TESSEYMAN, Head of Order Department, with the Pressed Steel Car Co. h., 1710 Irwin Avenue, Allegheny, Pa. — A. Stucki, M. C. Blest, J. L. Klindworth.

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BRUCE WALTER, Construction Engineer, American Steel Hoop Co., Etna, Pa., h., 323 Evaline Street, Pittsburg, Pa. — F. L. White, H. J. Glaubitz, A. Smith.

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CHAS. D. WETTACH, - Treasurer, - W. W. Lawrence Co. Inc., Water St., City, h., 1200 Linden Street, Allegheny, Pa. — W. H. Rodgers, G. S. Davison, W. G. Wilkins.

N. V. F. WILSON, Division Superintendent, Muncie, Ind. and Piqua, O. Plants, American Sheet Steel. h., Bridgeport, Ohio. — R. A. McKinney, C. L. Hastings, S. B. Ely.

LOUIS B. WHITNEY, - Treasurer, - Keystone Car Wheel Co., Pittsburg, Pa. 1209 Park Building, Pittsburg, Pa. — C. G. Hussey, C. B. Albree, C. W. Ridinger.

JOHN E. WHITTLESEY, District Manager, Heine Safety Boiler Co., Park Building, Pittsburg, Pa. — W. G. Wilkins, W. M. Judd.

DANIEL D. WILLIAMS, - Purchasing Agent, - Jones & Laughlins Steel Co. Pittsburg, Pa. — F. S. Slocum, T. O'C. Jones.

EDWARD WORCESTER, Jr., Shelby Steel Tube Co., 1820 Frick Building, Pittsburg, Pa. — R. T. Stewart, S. M. Kintner, D. Carhart.

THE PRESIDENT—I think it is a very great pleasure to all of us to hear this long list of names read out as applicants for membership in this Society. As you listen to this list you will note that it is a list of names of men who are managers, draughtsmen, foremen, etc., in all kinds of positions engaged in engineering work. In talking with a great many of our members, I find that each one sees this one and that one and another one that are not members of this Society, but ought to be. Eighty-seven is a large number, and yet the number of men in the city of Pittsburg who are connected with engineering work can be counted up in the thousands. This addition will make us something over seven hundred, and I think on a conservative estimate there are three thousand men in this community eligible for membership in an engineerng society like ours. Of course we don't expect to get them all, but we want to get the best of them. Now, the thing to do is for each one to interest as many as he can.

It was moved and seconded that the Secretary cast the ballot for the election of the applicants named. Motion carried.

MR. ENGSTROM—May I be permitted to say a word in connection with his election? In looking over the names of the members elected at the last meeting, I found there had been elected sixty-three new members, and I found fifty-nine endorsers. That looks like one apiece. Thirty-four had the name occur but once. They had done about one-third of their duty. Out of a hundred and ninety names, eighty-seven were past and present officers of the society. The whole society was almost beaten by a handful of officers.

THE PRESIDENT—Gentlemen you can draw your own conclusions. It is up to you to let us see what you can do at the next meeting. A very great many men in this city, who are eligible to membership in our society, would like to be members if it were properly presented to them, and if you present the matter to them there will be no trouble in getting them. We are glad to have them, yet the main thing is that this Society is worth a very great deal to any man, not only in its papers, but in the acquaintances he can make in this Society. If he goes to the meetings and sits like a bump on a log he will get nothing out of it as far as acquaintanceship goes, but if he talks to the man next to him that man

will get acquainted with him and it will do him good, not only in his professional career but in a social way. It is very much easier to do business with your friends than with your enemies, and I regard the social side of this Society, on acount of getting acquainted with each other, equal to the other advantages.

At the last meeting, as read in the minutes, the formation of a Mechanical Section was authorized and steps taken to start it. The gentlemen appointed called a meeting which was quite well attended and they decided to form a section. They have presented a petition to the Society as follows:

At a regular meeting of the Engineers' Society of Western Pennsylvania, held at the Society's House, No. 410 Penn Ave., Pittsburg, Pa., on Tuesday evening, January 20th, 1903, a committee having been appointed to consider the advisability of forming a Mechanical Section, and such section appearing to that committee to be desirable for the pursuit of special study in mechanical lines, the undersigned members of the Society hereby petition the Board of Direction for permission to form the Mechanical Section of the Engineers' Society of Western Pennsylvania:

SOCIETY OF WESTERN PENNSYLVANIA.

F. V. McMullin,
Gerald E. Flanagan,
H. M. Wilson,
M. C. Blest,
Reinhardt Daal,
Thos. Fawcus,
John L. Klindworth,
Geo. E. Klingelhofer,
Edward Garrick,
Nathan G. Smith,
A. Stucki,
John J. Muir,
Geo. K. Smith,
Richard Hirsch,
Willard J. Beach,
Francis S. Austin,
John J. Convery,
Sydney B. Austin,
Wm. E. Winn,
E. J. Mason,
Chester B. Albree,
Robert A. McKee,
Chas. B. Hidden.

I am informed that inquiry among the members has shown that there are a great many more than twenty-five who are very much interested in this section dealing with mechanical engineering problems, and questions of fuel, steam consumption, engine designing, blowing engines, or any number of allied topics The sec-

tion, as you will probably notice, in their last announcement, have gone so far wthout having been officially recognized. They have arranged for a meeting March 3rd. Mr. Edwin Fitts will read a paper on mechanical stokers. All who are interested in mechanical stokers are invited to be present. In other words, these section meetings are open to all our members. We want those especially who are interested in mechanical engineering to become members of this section. It is thought that these informal discussions will prove very interesting. In the chemical section they tell me that such problems have proved even more interesting to members than the regular papers, and that it has been of great personal benefit to those attending. When a question comes up one will turn to another and say, "How do you do this, or how do you do that?" and inside of five minutes you will have four or five different views of the same question. Each fellow thinks a little on his own lines, and by combining the thoughts of several men you will get pretty nearly the right method of doing a thing. They deal with questions perhaps a little too technical for the interests of the Society at large, but there is a place for both. The by-laws require that the formation of a section shall be first brought officially signed by ten members to the notice of the Board of Direction. The Board of Direction have passed favorably on the formation of this section, and it must now be presented to the Society.

Reads extract from Art. VI. By-Laws.

This section is now in full operation, although it is not legally formed. The matter will be presented at the next regular meeting of the Society, and I trust will be officially recognized, which I have no doubt it will.

In that connection at the last meeting a vote was taken to try to organize a section of designers and draughtsmen. A meeting was held last month with that end in view, and it was decided that it would be better to change the intent of such a section somewhat. While the name of the section really embraces almost any kind of designing, yet it was thought that it would be wise to change this section to what has been called a structural engineering section, a section embracing what you might call structural engineering, including bridge work, steel office buildings, founda-

tions, roofs, and all sorts of structural work in its broad sense. We have with us several gentlemen to-night who are personally identified with such work. I would like one or two to state how it impresses them, whether it would be desirable, etc.

MR. WHITED—Mr. President, there are, that I know of, at least three or four hundred men, and a great many more I do not know of, engaged in various kinds of structural engineering. As you have just stated, this embraces structures of almost any kind built of iron and steel, or granite and stone, or any kind of masonry. For those who are engaged in this work there are only a few apparently who have a good chance to talk over these points, and exchange their ideas, which will help solve the problems that come up to them. The difficulty is not so much to solve the problem as to find the best solution of the problem. In engineering a structure, it has to be built once for all. If any weakness ensues it is a serious matter. If a machine breaks down a new piece can usually be made nearly as cheaply as it could in the first place, but in structures it is different. It is a great help to a person engaged in that kind of work to be able to talk it over and find out how other people do a certain thing, and if they have seen any similar work done, how it worked out. That is the important thing. If a certain kind of foundation stands in a certain kind of soil better, or whether that method is successful or not, and what difficulties they encountered, that is the most important thing they have to consider. It seems to me that a section organized to discuss such things would be very valuable, and command a great deal of interest in the Society. I am in favor of giving it a trial.

MR. BARNSLEY—I think it is worth a trial at least. I think I can endorse very fully the remarks made by Mr. Whited.

THE PRESIDENT—I will take it upon myself to name a committee to meet together next Tuesday evening, the 24th. I will name Mr. Bowman, Mr. Whited, and Mr. Wilkins. I earnestly trust that all those here, who are connected with structural work, either in foundations, in coal tipples, office buildings, bridge building, or building work of any kind will invite their friends to this meeting, Tuesday evening, the 24th, in our hall here, and we will try to organize this section. I will endeavor

to send out notices to any of the men whom I know personally, and I trust that you will generally endeavor to disseminate the word.

I am sorry to have to announce to you the death of one of our members, Captain Jones. You will doubtless remember at our meeting about two months ago Captain Jones was on the program, and gave us a very interesting talk. A great many of you also will remember his toasts at at least two of our banquets. He was a retired navy captain and had been practicing engineering in Pittsburg for some time. He was a genial man and a very capable man. He was sick only a short time. I had a letter from his wife stating that he would be out in a few days and would correct his proofs, but instead he had a relapse. I think it would be in order to appoint a committee to draw up resolutions regarding his death.

It was moved and seconded that a committee of two be appointed to draw up the resolutions.

The motion was carried and the President appointed Mr. Ashworth and Mr. Davison.

THE PRESIDENT—I have one or two other matters to which I desire to bring your attention. I have a letter here from Dr. Alfred Mueller, of New York City, to the effect that the National German Engineers' Society are giving away Technical Dictionaries, under the title of "Technical Lexicon." They are published in German, English and French. Dr. Janneson, of Berlin, is Editor in Chief. They solicit the co-operation of societies in this country. The editor has gone to a great deal of trouble to get accurate and careful information. Blanks are furnished free. The only condition is that it shall be taken in seriousness, and that those receiving them will send in some words. The presumption is they are to be new words, and if any of our members desire to assist in this excellent work, if they will apply to the Secretary he will give them the address and put them in correspondence with Doctor Mueller on this question.

Just one more question before we announce the paper for this meeting. Mr. Victor Beutner, who is in charge of the tickets for the banquet is present to-night and for him I will say that he will be very glad to take the names of any desiring to

attend. We want every man to attend. While there may be a few men here to-night who have not the necessary four dollars in their pockets, I think he will be willing to take their names and they send check for the money later. It is very desirable to get the names in early. There are a great many duties devolving upon this committee, you will hardly realize the tremendous lot of work it takes to arrange these things. Now, to avoid any difficulties we earnestly request that you bespeak your tickets to-night if you can.

The one thing that the engineer has to do with more than with anything else in this world in a professional way is the question of measurements. Whether we are chemists, civil engineers, bridge men, rolling mill men, steel men, whatever industry we are connected with—electric light, or electricity in its various ramifications—we have to deal with measurements of volume, length, temperature, or any number of things, and to do our work intelligently it is necessary that we should have standards to work by. We have, all of us, in our different kinds of work had to deal with different standards, the metric system or the English system. We have found different standards existing. For instance, threads and thread diameters of pipe, and a great many things of that kind that in the past were a hopeless jumble. Each manufacturer had his own standard. A great many have come down to a manufacturer's standard. In railroading we have the master car builder's standard. These standards are based upon some different standards. The question is, are our standards which are the basis of the entire engineering profession correct? There are standards and standards—I could talk all night on them, from the ancient cubit down. But we have a gentleman with us to-night who is very much better prepared to speak on that subject and who has been selected by the United States Government on account of his knowledge of these matters to take charge of the National Bureau of Standards. I have the pleasure to introduce to the members of the Society, Prof. S. W. Stratton, who will tell us something of his work.

Prof. Stratton—On leaving Chicago I missed very much indeed my contact with and the association of engineers, and I can assure you I appreciate very much occasions like this, which

bring me once more in touch with the profession I expected to follow and for which I was educated. I understood there was to be some sort of an exhibit this evening, and I brought along a few standards. I will preface my remarks with a few words in connection with standards of length, as that is the one with which engineers are more intimately associated.

WEIGHTS AND MEASURES.

BY PROF. S. W. STRATTON, DIRECTOR OF NATIONAL BUREAU OF STANDARDS.

Notwithstanding the fact that Congress is authorized by the Constitution to fix the standard of weights and measures, and the subject has claimed the attention of many of our foremost statesmen and scientists from the beginning of the Republic, very little direct legislation has been enacted concerning the material standards to be employed by the Government or the public. The measures of length and weight of Great Britain were lawful in the Colonies prior to 1776, and though never adopted by Congress, they have, with several modifications, continued in common use up to the present time.

In 1814, or shortly after the organization of the Coast Survey, an 82-inch bronze bar with an inlaid silver scale was secured from the instrument maker, Troughton, of Lonon, for the use of the Survey. This bar was merely a copy of Troughton's Scale, and had not been compared with the British Yard, but the distance between the 27th and 63rd inches, which represented 36 average inches of the bar, was assumed equal to the British Yard at 62° Fahrenheit.

In 1828 Congress enacted a law making the brass Troy pound weight procured by the Minister of the United States at London in the year 1827, the standard weight to be used by the mint of the United States in the coinage of money.

On account of discrepancies existing among the weights and measures in use in the custom houses at our various ports, Congress in 1830 directed the Secretary of the Treasury to investigate the matter. As a result certain material standards were adopted by the Traesury Department, the yard was taken as the distance between the 27th and 63rd inches of the Troughton Scale. (The

avoirdupois pound was defined as 7,000/5,760 of the Troy pound of the mint and the gallon adopted was the old British Winchester gallon defined as 231 cubic inches and which has since been discarded in Great Britain.)

In 1836, the Secretary of the Treasury was further directed to furnish copies of all the standards that had been adopted by the Treasury Department to the States, and in this manner they became the practical standards for the United States. To carry on this work, the office of Standard Weights and Measures was organized under the Treasury Department.

The British Imperial Yard was destroyed by fire in 1834, and when the new standard was constructed to replace it, a number of copies were made, two of which, Bronze No. 11 and Low Moor Iron No. 57, were presented to the United States. These copies were received in 1856, and soon afterward were compared with the Troughton Scale, which was then found to be 0.00083 inch longer than the new Imperial Yard at the standard temperature of 62° Fahrenheit.

Bronze No. 11, as it is called, being an exact copy in form, material and construction of the Imperial Yard, superseded the Troughton Scale, and from 1856 to 1893 it was accepted by the Office of Weights and Measures as the representative of the British Standard. Once during this period, in 1878, it was taken to England and compared with the Imperial Yard. The result of this comparison indicated that No. 11 had shortened by 0.00016 inch. In fact, all the copies of the Imperial Yard have shown appreciable changes relative to that standard when compared at subsequent periods, and this has led to the suspicion that the length of the Imperial Yard is not itself constant.

The metric system was made legal throughout the United States in 1866, but the standards of this system were not then satisfactory and in 1875, more than half a century after John Quincy Adams had recommended a conference between nations for the purpose of establishing world-wide uniformity in standards, such a conference was held—the United States being one of the participants. As a result, there was established in Paris a permanent International Buraeu of Weights and Measures. Many of the leading scientists of the world were engaged for several

years in perfecting prototypes of the metric standards, and in 1889 these were ready for distribution among the seventeen nations represented in the International Conference. Two copies each of the standard meter and kilogram were sent to this country, and were placed in the custody of the Secretary of the Treasury. Shortly after the receipt of the national prototypes of the meter and kilogram, a careful determination of the relation of the Imperial Yard to the International Meter was made at the Office of Standard Weights and Measures, and as the relation found differed from that legalized in 1866 by less than the uncertainty of the comparison, it was decided to adopt the meter as the fundamental standard of length and to define the yard in terms of it, according to the relation established by Congress, viz., one meter equals 39.37 inches, or one yard equals 3,600/3,937 meter. Not only is the constancy of the length of the Imperial Yard suspected, but in addition the lines, which are about 1/1,000 of an inch wide, are much too broad for present requirements. On the other hand, the International Meter and its copies represent the most advanced conception of standards of length. They are made of platinum with 10 per cent. iridium, and were constructed and compared with the greatest precision under the direction of an International Committee at the International Bureau of Weights and Measures situated upon neutral territory near Paris, France, and which is maintained by contributions from all the principal nations. It therefore appeared that greater accuracy and stability would be obtained by regarding the meter as the sole and fundamental standard of length and an executive order to this effect was issued by the Secretary of the Treasury on April 5, 1893. At the same time and for similar reasons the kilogram was declared to be the fundamental standard of mass.

Whatever may be added as to the necessity of uniformity and reliable standards used in commerce and trade is equally true of the standards used by manufacturers and scientific investigators. These interests require standards of the very highest order of accuracy and of far greater variety than heretofore, such as standards of high and low temperature, pressure, standards of illumination, electrical standards and many others. Frequently the benefits to be derived by the public from fixed and reliable

standards are through the medium of meters and precise measuring apparatus, such as balances, apparatus for the measurement of lengths, capacity, graduated glassware, pressure gauges, thermometers, barometers, metrological apparatus, photometers, gas and water meters, voltmeters, ammeters, wattmeters, the instruments used in surveying, navigation and hydrography, and many other instruments. That the graduations and indications of these instruments should agree with the fundamental standards is a question of the most vital importance; and without the facilities for such tests and comparisons, the public is deprived of the greatest benefits to be derived from such standards as may have been recognized by the Government. German and English makers of measuring apparatus furnish official certificates with their instruments, and the value of such certificates is so well recognized that we find our own manufacturers quoting prices on apparatus which has ben verified in the standardizing institutions of foreign governments.

It was this condition of affairs that led Congress to enact a law, March 3, 1901, establishing the National Bureau of Standards, the functions of which may be briefly stated as follows: The comparison of the standards used in scientific investigations, engineering, manufacturing, commerce and educational institutions, with the standards adopted or recognized by the Government, the construction when necessary of standards, their multiples and subdivisions, the testing and calibration of standard measuring apparatus, the solution of problems which arise in connection with standards, the determination of physical constants and the properties of materials. The bureau is authorized to exercise its functions for the Government of the United States, for State or municipal government within the United States, for scientific societies, educational institutions, firms, corporations or individuals.

The act establishing the bureau also provided for a suitable site which has been selected in the most desirable section of the suburbs of Washington, in a neighborhood particularly free from mechanical and electrical disturbances, but sufficiently easy of access.

The scientific work of the bureau will be under the immediate supervision of a director, assisted by a corps of physi-

cists and chemists. These men have been carefully selected by civil service examinations prepared with reference to the kind of work to be undertaken. The law also provides for a Visiting Committee of specialists, each appointed for a period of five years. At present the committee consists of President H. S. Pritchett, of the Massachusetts Institute of Technology; President Ira Remsen, of Johns Hopkins University; Professor Elihu Thomson, electrical engineer; Professor Edward L. Nichols, professor of physics, Cornell University, and Mr. Albert Ladd Colby, metallurgical engineer.

Immediately upon the organization of the bureau temporary quarters were secured in the building occupied by the U. S. Coast and Geodetic Survey. It was soon found that these were insufficient even for preliminary work, and on July 1, 1902, a large four-story residence building in the immediate neighborhood was secured as a temporary laboratory. This building will provide space for the organization of the more important lines of work and for the collection and testing of the apparatus to be used in the equipment of the permanent laboratories when completed.

The work for which the National Bureau of Standards was established includes research and testing in the domain of physics, extending into the field of chemistry on the one hand and of engineering on the other. The union of research and testing in one institution is of supreme importance, the investigations being of course designed to carry the work of standarization and testing to the highest possible efficiency.

The laboratory requirements are therefore those of a research laboratory plus whatever special facilities may be needed for commercial tesing. For the purpose of securing these conditions, two buildings have ben planned, one of which, the mechanical laboratory, is now nearing completion and will contain the mechanical and electrical plant, instrument shop and laboratories for experimental work or testing requiring considerable power or large currents. This building is 135 feet long by 51 feet wide, a large extension of the first floor increases its area by nearly fifty per cent. This floor will include a boiler room, large enough to contain the boilers, pumps, tanks and other accessories necessary for the present equipment and a reasonable amount of

expansion, a large engine and dynamo room, with engines, both for power and experimental purposes; a room for the refrigerating and liquid air plants, storage battery room, and rooms for the heating and ventilating apparatus. Provision is also made for gas plant, coal supply and store room. The second floor will include an instrument shop and several laboratories for electrical work requiring heavy currents. The rooms of the third floor will be used for electrical work and other testing. Provision will be made in this building for the testing of water and gas meters, pressure gauges, indicators, anomometers, tachometers, etc.

The physical laboratory recently begun is 172 feet long, 53 feet wide and will be four stories high with a spacious attic. The building will be of extra heavy construction and will be well lighted. The rooms of the first two floors will be reserved entirely for experimental purposes. They will be practically constant temperature rooms with automatic temperature control, double windows and light-tight shutters for darkening the rooms when necessary. They are also provided with all of the usual laboratory facilities, with ample ducts and spaces for placing wires or pipes that may be needed in the future. This building will contain laboratories for testing and investigations in connection with length, mass and capacity. The space allotted to the subject of electricity will include laboratories for research and the more refined measurements in connection with electrical standards, measuring instruments, constants, the electrical and magnetic properties of materials. The subject of thermometry is amply provided for, and some of the best laboratories will be set aside for general research. The third floor of the building will be devoted to a library, museum, the offices of administration and a moderately large lecture room. The fourth floor will be fitted up as a chemical laboratory. The buildings are connected by a tunnel 170 feet long, one part of which will serve as a passage way between the two buildings, also for wires, pipes and ducts of the heating and ventilating system, the other part will be used as a laboratory for testing steel tapes and for experiments requiring a long distance. The buildings will be heated by the double-duct system, with provision for heating the air supplied in cold weather or cooling it in warm weather, the proportions of the mixture

being regulated by means of automatically controlled dampers. Each room has its own supply duct, regulating dampers and thermostat. The latter may be set at any desired temperature within the range of the apparatus. When necessary the humidity of the air furnished to any laboratory may be controlled. The general laboratory facilities will include gas, compressed air, vacuum. Hot and cold water, ice, cold brine, liquid carbon dioxide and liquid air will be provided for the production of low temperatures. Gas and electric furnaces will be available for high temperatures. The electrical equipment will include the dynamos, motors, storage batteries, transformers and other apparatus for the production of the range of current and voltage necessary for experimental purposes, and the testing of commercial instruments.

In addition to the heating and ventilating system there is a separate exhaust system connected to the laboratories. These exhaust flues will be provided with a fan sufficiently strong to secure a positive draft for carrying off all fumes or vapors that may be generated in these rooms.

The work of the past year has involved the verification of a large number of standards of length, mass and capacity for the Government, scientists, manufacturers, engineers, State and city sealers of weights and measures.

In the field of electricity, the bureau is already prepared to undertake the verification of precision standards of resistance, electromotive force and capacity, also ammeters, voltmeters and wattmeters, within a limited range, which will be extended to meet all of the requirements of commercial instruments as soon as the bureau is established in the permanent quarters. The testing and investigating in connection with alternating current measurements and instruments are being developed as rapidly as possible, and the services of the bureau in this line will soon be offered to the public. Provision is also being made for the determination of the magnetic properties of materials.

The subject of photometry was among the first and most important subjects considered by the bureau. Much of the apparatus for this work has been installed, standards have been secured and the preliminary investigations are under way. Manu-

facturers abroad have been quick to realize the great importance of an accurate knowledge of the temperature in many lines of work, and these questions are now beginning to receive due attention in this country. The lack of proper attention to this question is undoubtedly due to the absence of suitable standards of temperature, for the indications of the various pyrometers found on the market yield widely different results and consequently lead to confusion and loss of confidence, and this, in a great measure, not due to inferiority in construction of American instruments, but is inevitable as the manufacturers could not obtain uniform standards, so that each maker was compelled to establish his own scale of temperature as best he could with the facilities at hand. The result has been that American manufacturers have been compelled to go abroad for reliable standards which are certified by foreign testing bureaus.

The liquefaction of air and other gases on a large scale has opened up a new and important field of research on the properties of matter at extremely low temperatures, and necessitates instruments for measuring these temperatures.

To meet these requirements the bureau has acquired and constructed standards, special apparatus and methods for testing and comparison have been devised, and the bureau will soon be in a position to test and investigate the entire range of temperature measuring instruments.

The relation of the bureau to the engineering, manufacturing and scientific interests of the country will be very important, and it is hope that it will become far more comprehensive than a mere standardizing institution. It is not to be expected that an engineer or manufacturer can keep in touch with the scientific development of this and other countries, and the scientist rarely has the time or the inclination to develop the practical applications of scientific discoveries. Hence there is every reason why this institution should become eventually a bureau of information where manufacturers and engineers may go for assistance and information along scientific lines, especially in connection with methods of measurement, the properties of materials or physical constants. It will not be the policy of this bureau to adopt arbitrarily technical standards used in any particular branch of manufacturing,

but when such interests agree as to the best standards in any particular case, the bureau will undertake to determine whether the articles submitted conform to the standards agreed upon by those interests. In all such cases the bureau will when called upon give advice and assist in every possible way in the adoption of technical standards. The progress of manufacturing and many commercial industries follows very closely the scientific development of the country. The Government expends over a million dollars annually in maintaining an elaborate system of agricultural experiment stations throughout the country in order that the agriculturalist may have the benefit of scientific investigation. Why should not the manufacturer be assisted in the same way?

REMARKS—You would be surprised at the laxity there is in matters of this kind in our large cities. You will find in some of them no regulation at all. This has not been from lack of interest in this matter. Not long ago we had a request from the Mayor of Chicago to tell him what to do in order to make his office an efficient one. He said if we would tell him what to do he would instruct his men in a general way, and try to make it a model office. Within the last week we have had a similar request from the Mayor of New York. I think the usefulness of the bureau in even this line, in the ordinary affairs of daily life, will pay for its establishment. Our manufacturers of scientific apparatus have had difficulty in keeping up with foreign manufacturers. This is due somewhat to the fact that scientific institutions are allowed to import free. I think the fact is more largely due to the interest foreigners have taken in this class of work. The quality of the German apparatus and the reputation it enjoys is due almost entirely to the effect upon its manufacture which the German certificate has in assuring its accuracy to the purchaser. We hope our maufacturers will avail themselves of this bureau. In fact they are doing so. We have established friendly relations with the manufacturers, and the advantage of the bureaus will be very great indeed.

I will place some labels on these standards but will ask you not to handle them. I hope that all will have an opportunity to see them. I thank you very much for your attention.

PROF. KINTNER—The lantern is in working order, if you wish to throw the pictures on the screen.

Prof. Stratton then showed a number of views and plans of the buildings.

"Now, as I said before, I will label these standards. Before that, if there are any other questions, I will be glad to answer them."

A MEMBER—Is that bronze bar the legal standard of length?

PROF. STRATTON—As I stated there are none of our standards except the meter, that have ever been legalized by Congress. Congress has never made any of these legal directly, except possibly the meter and the kilogram.

MR. FISHER—What means do you employ in measuring such very small fractions of an inch?

PROF. STRATTON—The ordinary form—two large microscopes mounted upon very rigid supports.

MR. FISHER—What firms in this country do you consider make the best thermometers, or is there one that makes better than another?

PROF. STRATTON—Now that is one thing that we have to be very careful about—what we say. We don't propose to make ourselves an advertising bureau. If a user or maker wishes to submit them to the Bureau for inspection, we tell him the truth about it to the best of our ability. I will give you an illustration of how careful we must be about this thing. Not long ago one of the makers of electrical apparatus sold a resistance box to the Government. It did not come up to the guarantee. It would be hardly fair to this maker, not having the advantages of the Bureau, to report in the case. A suggestion was made which he took advantage of. Very soon afterward his standards were sent to us for inspection. In that way we will assist him to turn out the right product, and we will do it by coöperation rather than by criticism directly. This has happened in the case of other makers also. They are all on the same basis as far as that is concerned. In the case of clinical thermometers, we took up the standardization of them, and we have found several good makers of clinical thermometers. We asked each to submit a lot for inspection. Each submitted fifty odd thermometers, and while the

thermometers submitted agreed with others of the same manufacture, yet the product of the different manufacturers did not agree with each other. We asked them to submit a standard. This was done in many cases, and in many cases we found them so wrong that they could not be used in the most ordinary work. They are very ready to take advantage of the offer of the Bureau. It is our duty first to coöperate with a maker and put him in line of making the correct thing. In this way we get the benefit of their practical experience and in many cases we get a good many very good ideas. Our plan is to coöperatae with the manufacturer at least for the first few years to first put the manufacturer in the way of turning out a good product before we criticise his product. We have had submitted various varieties of standards. Those that have already come in are of so great a quantity that it has been ten times as great as we could care for.

A MEMBER—Are you at present equipped for making tests of pyrometers?

PROF. STRATTON—Yes, we have the means, but we wish to get things in good condition for doing this work before we begin with the public. That means the establishing of our own standards and furnaces which we will use, and that work is nearly all done. We will issue a circular in regard to pyrometers within the next two or three months, and also instruments for measuring low temperatures.

A MEMBER—I would like to ask how much discrepancy there is in the American clinical thermometers. I bought one from a dealer not long ago, and while looking at them he said if I would pay a little more I could get one with a certification on the back of it. I purchased one of that kind and not long afterward I was fortunate enough to have three or four doctors in, and I found my thermometer was higher than theirs. Theirs agreed with each other but mine was one degree higher.

PROF. STRATTON—We find two degrees the maximum. We have devised an apparatus for testing these in lots of twenty-five. One hundred may be put in the bath at one time. We hope to make the cost for this in all cases so small that manufacturers will submit them to us in large quantities. We get clinical thermometers from manufacturers in lots of one hundred.

MR. FISHER—At two thousand to three thousand degrees how close can you measure degrees to be absolutely sure of it? I speak of Farhenheit degrees.

PROF. STRATTON—With the thermal couple, perhaps within two, three, or four degrees. Of course the higher you go the more difficult it is to measure. The chances are that the instrument may be out fifty to one hundred degrees as ordinarily used in practice.

MR. STUPAKOFF—I have had considerable experience with pyrometers, and you cannot depend upon the accuracy of the instrument. They will get slightly damaged even in carrying them from room to room.

PROF. STRATTON—We all know they are very far from being perfect. It does not mean much to test these instruments because when putting them in place they will get out of order. It may be we can devise means for testing them from time to time and studying them to find out just what the trouble is in these cases. Pyrometers provided with the best certificates will, with a little use, change so much that we must have means for frequent tests.

MR. FISHER—Do you favor making measurement of temperature by the resistance coil?

PROF. STRATTON—It depends upon conditions. Up to 800 degrees it is all right. There it begins to fail. You should use the couple from that range.

MR. FISHER—Does the couple change in time from usage?

PROF. STRATTON—Yes, it will change in time. I am not an expert in pyrometers. I am not an expert in all departments of this Bureau. I do think we have one of the best experts in this country. The first of July we will have three men working on the subject of pyrometers—not only that, but improved methods of measurements. There is a great field for improvement in pyrometers and also in photometers.

THE PRESIDENT—Gentlemen, we have had the pleasure of listening to a paper of a somewhat different nature to anything we have ever heard before. We have had papers on a very great many different subjects, but I think the one to-night is unique. I think we are especially favored in having this exhibit of Standards. I have seen them myself in Washington in the past, at least some

of the Standards, but to have them brought out for our inspection is a very great honor to this Society. We have also some other instruments of more or less precision. I won't say of absolute precision after what has been said. We have here a circle, graduated I don't know how fine, but I should imagine down to about one hundredth part of a second of an arc. It is well worthy of your inspection. I hear that these instruments will be shown to the members under better condition at a visit to the new observatory in the course of a few weeks. We are contemplating a visit in May or June to the observatory, and to the Western University, and Doctor Brashear's works. It promises to be of unusual interest. Professor Wordsworth will have these instruments and others at work. We had a little outline of it a year or two ago.

I would like to call your attention also to the very earnest efforts made in your behalf for this evening's pleasure by Prof. Kintner. We have the lantern which belongs to the Western University, and which was procured by him. He came down and unpacked the instrument and did a great deal of other work, so much that I find he has not yet had his dinner. I venture to say there are few members willing to do that much for the Society, and when we have a man of that kind, we appreciate him.

There is another matter that I wish to speak of, and that is the dinners at the University Club. The dinners there have been very pleasant to those who have been present. The number has been uncertain. It will be taken as a special favor on your part if you will notify the reception committee. We want you all to come. To-night we had only a very few names in and more came than sent word. It is very difficult to have any Hotel or Club arrange a dinner for an uncertain number of people.

I will again remind you that Mr. Beutner is prepared to provide you with banquet tickets.

The next meeting will be on the general subject of concrete. You have heard Prof. Stratton's remarks about concrete floors. We expect to have papers on laying floors, on testing cement, and on the manufacture of cement, and we hope to have some of these papers of such practical nature that no engineer of our Society can afford to be away from that meeting.

Please remember that the Structural Section will meet Tuesday evening, the 24th of February, in this room.

MR. FISHER—I move that this Society extend to Prof. Stratton its hearty thanks for his excellent paper, and for the trouble he has gone to in bringing his Standards for our special interest.

Motion carried.

THE PRESIDENT—I would ask all present to come forward and examine the apparatus. They will find on the table some measures, such as are found in use every day, provided by the Stieren Company: If you keep in motion you can all see them.

MR. *ENGSTROM*—We have not had a report from any of the committees.

THE PRESIDENT—There are no committees to report.

MR. ENGSTROM—At a previous meeting there were some suggestions about the reception committee receiving the new members and introducing them to the old members. Since that time it has become more important. Of course it is a well known fact that people are very ungrateful, but I am sure that all that is needed is to call attention to this matter, and make this reception committee a reception committee in fact.

THE PRESIDENT—I attended that meeting. As to the question of making new members acquainted with the older members, I think there is no way to introduce them. With a membership as large as ours it is impossible for one man to know all the others. A great deal depends upon the new member himself, and it only remains for a stranger to speak to the man next to him and make himself known.

MR. WHITED—I would suggest that the application blanks for membership in this Society have three names on the bottom and I would suggest that members having their names on the application introduce the new member to the members of the Society.

MR. BARNSLEY—I am very glad to have that remark made, because with this large membership I am quite sure if the reception committee would undertake to know all the members they would work twenty-four hours per day The present reception committee is glad to do anything to make the members acquainted. If the endorsers will come forward and introduce them, the reception committee will be glad to meet them. We are prepared to do

everything in our power. We started out with a smoker, at the same time an announcement was made of what we proposed to do. I am sorry to say that the smoker was poorly attended. We had only an attendance of sixty-five and our expectations were not at all met. Now, it would be a very gratifying thing to us if for the next smoker the members will bear in mind to be on hand and do their duty as well as the reception committee hopes to do theirs. I have no report to present to-night, only to say that the smoker was poorly attended. In this same connection, to-night the attendance at dinner was very small indeed. Only twenty-four appeared. We should have forty or fifty at least.

A MEMBER—With reference to application sheets, I wish to call your attention to the fact that at least one-half of those signed to-night were signed by our President and Secretary. It would be a pretty difficult job for them to appoint themselves a reception committee.

THE PRESIDENT—One reason for that is, by virtue of our positions occassionally we endorse a man whom we do not know personally, but at the request of someone who does know all about him. You will realize that the character of the membership coming into the Society is very desirable. What you say is true: personally I could not recognize all those whom I have endorsed.

MR. BARNSLEY—In that connection I also want to remind the members, especially the new ones, that as soon as a man is elected a member of this Society he is one of us. If he is a stranger he should just come forward and announce himself and say, "I am a new man, I would like to meet this man or that man." We are all here on the same footing and have equal rights. It comes under the old principle of "Help those who help themselves."

THE PRESIDENT—It has just been said that we are all equal in this Society, whether millionaires or paupers. This Society is not a charitable institution, not dependent on any man's bounty, and we do not ask any favors from anybody. We meet here for our mutual good and we are proud of the fact that we are not dependent upon anybody's bounty.

If there is not further business a motion to adjourn is in order.

A MEMBER—Mr. President, in regard to the matter of acquaintanceship of new members it might be a good idea for the new members to be introduced at a subsequent meeting by the President, to the Society at the President's stand, so that the members will all know who the new members are.

THE PRESIDENT—I fear if I were to have a procession of eighty-seven gentlemen passing here they would not make a very definite impression on your minds.

MR. ENGSTROM—You might take them in sections.

On motion the Society adjourned at 10:45.

CHARLES W. RIDINGER, Secretary.

STRUCTURAL SECTION.

On February 24, 1903, a special meeting was held in the rooms of the Engineers' Society of Western Pennsylvania, 410 Penn avenue, Pittsburgh, pursuant to a call issued by the President of the Society for the purpose of forming a section of the Society devoted to Structural Engineering, this to include all engineering structures built of wood, iron, steel or masonry.

Meeting called to order at 8:25 by President C. B. Albree, who stated the purpose of the meeting and called for nominations for temporary chairman and temporary secretary. J. K. Lyons was nominated for the former and Willis Whited for the latter office. Both unanimously elected. Moved and seconded that a committee of five be appointed by the chairman to prepare by-laws for the section. Amended by making the number three, carried. Chairman appointed L. F. W. Hildner, Chas, Worthington and L. J. Affelder. On motion a committee of three was appointed by the chairman to nominate permanent officers for the Section and report at the next meeting. Chairman appointed W. G. Wilkins, E. K. Morse, G. T. Barnsley.

Moved and seconded that the regular meetings of the Section be held on the fourth Tuesday of each month, carried. On motion a special meeting was called for Tuesday, March 10, 1903, to hear reports of committees.

A brief discussion was had on the subject of full-size tests for eye-bars, participated in by J. K. Lyons, C. Worthington and Willis Whited. By request E. K. Morse related some of his experiences in Australia during the erection of the Hawksbury Bridge. A member proposed the subject of knee-braces in buildings for discussion. Briefly discussed by J. K. Lyons, C. Worthington and Willis Whited. Subject assigned for discussion at meeting to be held Tuesday, March 10. Floors for Highway and Street Bridges.

WILLIS WHITED.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and thirty-third regular monthly meeting of the Engineers' Society of Western Penn'a. was held in the Lecture Room of the Society's House, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, March 17, at 8:30 o'clock.

The president, Mr. C. B. Albree, in the chair, and 147 members and visitors present. Minutes of the preceding meeting were read and approved.

The Board of Directors reported that they had passed favorably upon the following applications for membership and present same to the society for action.

NAME.	OCCUPATION.	ENDORSED BY
WALTER M. ALSTON,	Draughtsman, h., 1212 Buena Vista st., Allegheny, Pa.	F. V. McMullin, J. J. Convery, A. M. Acklin.
HARRISON E. ASHLEY,	Chemist, Salem Iron Co., Leetonia, Ohio. Box 291, Leetonia, Ohio.	J. M. Camp, H. W. Craver, H. E. Walters.
J. F. BAKER,	Draughtsman, Oil Well Supply Co. h., 6356 Marchand street, Pittsburg, Pa	J. M. Searle, D. Hunter, Jr., F. V. McMullin.
J. H. BAKER,	Manufacturer of Forgings h., 1240 Palo Alto st., Allegheny, Pa.	B. M. Everson, S. M. Kintner, C. B. Connelley.
S. F. BARTH,	Construction Department, Riter-Conley Mfg. Co., Water street, Pittsburg, Pa. h., 1205 Monterey street, Allegheny, Pa.	D. F. Hildner, H. M. Wilson, Z. H. Sikes.
GEO. F. BAUER,	Civil Engineer, With Pittsburg Railways Co. h., 101 New York avenue, Rochester, Pa.	S. M. Kintner, D. Carhart, A. E. Frost.
JOHN D. BIGGERT,	Pres. Pittsburg Trolley Pole Co. and Keystone Forge & Machine Works. Tradesmen's Building, Pittsburg, Pa.	B. M. Everson, C. W. Ridinger, A. E. Ensign.

JAMES BLACK, Jr. - Draughtsman, - {F. V. McMullin, F. S. Austin, C. W. Laing.}
Pressed Steel Car Co.
h., Idlewood, Pa.

ERASTUS BOND, - Civil Engineer, - {W. H. Smith, R. H. Stevens, B. H. Taylor.}
National Steel Co., Mingo Junc. Ohio.
h., 620 Market street, Steubenville, Ohio.

H. A. BRASSERT, - Superintendent, - {J. M. Camp, C. Mercader, C. W. Ridinger.}
Edgar Thomson Steel Works.
Braddock, Pa.

J. H. K. BURGUEIN, - Treasurer, - {V. Beutner, E. Kaufman, C. W. Wright.}
Westmorland Steel Co.
424 Fourth avenue, Pittsburg, Pa.

JOSEPH C. BARR, - Contracting Engineer, - {C. B. Albree, C. W. Ridinger, J. M. Camp.}
807 Pittsburg Bank for Savings,
Pittsburg, Pa.

W. H. COOPER, - Contracting Engineer & Supt. - {C. W. Ridinger, H. D. Hershey, W. D. Hough.}
Oil Well Supply Co., Oil City, Pa.
h., 154 West Third street, Oil City, Pa.

W. D. CORCORAN, - President, - {W. C. Wilson, C. B. Albree, C. W. Ridinger.}
Central Pipe Valve & Construction Co.
914 River avenue, Allegheny, Pa.

JOSEPH V. CRAINICH, - Engineer, - {T. H. Johnson, D. Y. Swaty, C. W. Ridinger.}
Penna. Manor Shaft, Shoenberger &
Blaine Coal Co's. h., 811 Clarissa street, Pittsburg, Pa.

STEWART A. DAVIS, - Division Superintendent, - {W. H. H. Ginder, A. C. Beale, A. Pinkertine.}
American Sheet Steel Co.
h., Vandergrift, Pa.

WM. McC. DOULEY, - Ass't. City Engineer, - {F. H. Schwartz, M. A. Tenney, Willis Whited.}
of Pittsburg.
h., 147 Meridan street, Pittsburg, Pa.

LUTHER L. EMERSON, Manager Pittsburg Office of {S. B. Whinery, C. B. Albree, C. W. Ridinger.}
Clark & McMullen Consulting
Engineers, 20 Broad street, New York City. 526 Frick Building, Pittsburg, Pa.

ERIC ESSELIUS, - Mechanical Engineer, - {W. H. Smith, R. H. Stevens, B. H. Taylor.}
National Steel Co.
National Steel Co., Mingo Junction, Ohio.

PRESLEY J. FICKINGER, - Master Mechanic - {R. R. Richardson, J. M. Camp, C. W. Ridinger.}
Pittsburg & Conneaut Dock, Con't. O.
h., Conneaut, Ohio.

CHAS. W. FRIEND, - Vice Pres. & General Mgr. - {A. B. Harrison, C. H. Rich, J. M. Camp.}
Clinton Iron & Steel Co.
Box 177, Pittsburg, Pa.

LAWRENCE H. GIBSON, Pittsburg Representative, {V. Beutner, N. C. Wilson, J. W. Landis.}
of Cleveland Punch & Shear Works Co.
and Cleveland Crane & Power Co. Frick Building, Pittsburg, Pa.

CHAS. H. GISIN, - Draughtsman, - {G. E. Flannagan, M. B. Miller, F. O. Schatz.}
With Julian Kennedy.
h., 208 Chestnut street, Avalon, Pa.

R. W. GRANGE, Jr. - Civil Engineer, - {A. E. Wells, F. Engstrom, C. W. Ridinger.}
With Jas. Stewart & Co.
h., 4732 Wallingford street, Pittsburg, Pa.

JOSEPH A. GRENIER, Bridge and Str'al Draug'n, {P. Vierheller, R. Khuen, Jr., J. K. Lyons.}
A B. Co., 51st street, Pittsburg, Pa
h., 764 Forest avenue, Avalon, Pa.

REUBEN C. HALLETT, Manager Pittsburg District for the Automatic Heating Co. {V. Beutner, E. H. Haslam, W. B. Robinson.}
General Office: Maratime Building, Battery Park, N. Y. City.
1402-3 Keystone Bank Building, Pittsburg, Pa.

WM. B. HARTMAN, - Foreman, - {F. Wadsworth, S. M. Kintner, C. B. Albree.}
J. A. Brashear Co., Ltd., Allegheny, Pa.
h., 1927 Perrysville avenue, Allegheny, Pa.

WM. H. HEGMAN, - Superintendent, - {J. M. Camp, A. G. McKenna, C. Wheeler.}
Firth-Sterling Steel Co
h , Oakmont, Pa.

JAS. B. HOGG, - Division Engineer, - {E. Hough, B. H. Taylor, W. H. Smith.}
H. C. Frick Coke Co
h., Latrobe, Westmoreland Co., Pa.

WM. E. WORLEY, Eng., Insp. and Sup. Arch., {F. A. Ensign, C. W. Ridinger, H. D. Hershey.}
Westinghouse Building, City.
h., Crafton, Pa

WM. R. LUDEWIG, - Instrument Maker, - {F. Wadsworth, S. M. Kintner, C. B. Albree.}
With the J. A. Brashear Co., Ltd.,
Allegheny, Pa.

JOHN A. HUNTER, Mechanical Engineer, {S. B. Whinery, C. B. Albree, C. W. Ridinger.}
American Steel & Wire Co., Pittsburg, Pa.
h., 6356 Marchand street, Pittsburg, Pa.

JAMES E. JONES, - Superintendent, - {J. Fawell, I. S. Seaman, B. E. Whinery.}
Seaman Sleeth Co.,
Care of Seaman Sleeth Co., Pittsburg, Pa.

ARTHUR KALLOCK, - Connected with - { S. Diescher, C. W. Ridinger, J. M. Camp.
Epping Carpenter Co., Pittsburg, Pa.
h., 427 Fairmont avenue, Pittsburg, Pa.

HUDSON F. LAXTON, - Assistant Engineer, - { E. Schwartz, W. Whited, M. A. Tenney.
Bureau of Engineering and Construction, City Hall, City.
h., 5016 Liberty avenue, Pittsburg, Pa.

THOS. M. LOVELLE, Eng. Yards and Building, { R. Khuen, Jr., J. K. Lyons, J. Williams.
American Bridge Co.
h., Economy, Beaver Co., Pa.

FRITHIOF LUNDAHL, Mechanical Engineer, { F. Engstrom, C. L. Hastings, E. Swensson.
Bethlehem Steel Co.,
S. Bethlehem, Pa.

C. W. LYTLE, - - With - - { V. Beutner, E. Kaufman, C. W. Wright.
Vulcan Foundry & Machine Co.
h., New Castle, Pa.

M. M. MANEESE, - Draughtsman, - { M. Knowles, M. A. Tenney, C. W. Ridinger.
At Municipal Hall, Pittsburg.
h., 605 Murtland avenue, Pittsburg, Pa.

D. L. MACOMBER, - - Manager, - - { John Hare, J. W. Landis, N. C. Wilson.
Pittsburg Office of Pratt & Whitney Co.,
1224 Frick Building, Pittsburg, Pa.

FREDERICK S. MARTIN, Superintendent, { G. F. Freed, C. W. Ridinger, A. E. Ensign.
R. D. Nuttall Co.'s Works.
h., 1914 St. Clair Terrace, Allegheny, Pa.

JAMES S. MARTIN, - Draughtsman, - { S. F. Hildner, Z. H. Sikes, H. M. Wilson.
Riter-Conley Mfg. Co.
h., 221 Jucunda street, S. S., Pittsburg, Pa.

J. T. MILLER, Secretary and Contracting Agent, { Geo. Davison, W C. Hawley, G. R. Harlow.
Penna. Water Co.
h., 424 Maple street, Edgewood Borough, Pa.

GRANT McCARGO, - President, - { C. B. Albree, H. W. Fisher, S. B. Dusinberre.
Penna. Lubricating Co., 34th street,
Pittsburg, Pa.

FRANK McCOY, - - Salesman, - - { W. H. Rodgers, G. S. Davison, C. W. Ridinger.
For the St. Louis Car Co.
h., 712 Rebecca avenue, Wilkinsburg, Pa.

JAS. E. McNARY, Eng. and Machinery Sales Agent, { C. W. Ridinger, H. D. Hershey, A. E. Ensign.
716 Empire Building,
Pittsburg, Pa.

EDWARD T. PARKER, - Draughtsman, -
Standard Steel Car Co.
h., 5 Burgess avenue, Allegheny, Pa.
{F. L. Irwin,
J. E. Tesseyman,
A. Stucki.

THOMAS E. PARNELL, - - With - -
Westmoreland Steel Co.,
424 Fourth avenue, Pittsburg, Pa.
{V. Beutner,
E. Kaufman,
C. C. Wright.

J. F. H. PAUL, - Chief Engineer, -
Vulcan F. & M. Co.
h., New Castle, Pa.
{V. Beutner,
E. Kaufman,
C. C. Wright.

PEDER PAULSEN, Mechanical Engineer,
Epping-Carpenter Co.
h., 110 Graham street, E. E., Pittsburg, Pa.
{S. Diescher,
A. J. Diescher,
C. W. Ridinger.

JOHN PERCIVAL, - Civil Engineer, -
For Pittsburg Railways Co.
h., Finleyville, Washington Co., Pa.
{S. L. Tone,
E. K. Morse,
A. Barnes.

SAMUEL S. POSEY, Sup. of Const. and Gen. Labor,
Mingo Works of Carnegie Steel Co.
Carnegie Steel Co , Mingo Junction, Ohio.
{W. H. Smith,
R. H. Stevens,
B. H. Taylor.

WM. C. RAE, - - - With - - -
Chandler & Co., Farmers Nat. Bank Bldg.
h., 5 Riverview avenue, Allegheny, Pa.
{C. W. Ridinger,
H. D. Hershey,
W. B. Hough.

MORRIS L RAGOLINER, - Draughtsman, -
Heyl & Patterson.
h., 1239 Fayette street, Allegheny, Pa.
{F. V. McMullin,
W. E. Winn,
E. J. Mason.

JOHN M. RAYBURN, - Assistant Engineer, -
With S. M. Taylor,
615 House Building, Pittsburg, Pa.
{W. E. Fohl,
T. H. Clagett,
C. W. Ridinger

JOSEPH L. SEAMAN, Jr., - Superintendent, -
Seaman Sleeth Co.,
41st street and A. V. R. R., Pittsburg, Pa.
{J. Fawell,
I. S. Seaman,
B. E. V. Luty.

JOSEPH A. SHINN, Manufacturing Slag Sand,
h., 5817 Alder street,
Pittsburg, Pa.
{F. Z. Schellenberg,
T. P. Roberts,
H. C. Gould.

H. C. SIEBERT, - Mechanical Draughtsman, -
Isabella Furnaces, A. S. H. Co., Etna, Pa.
215 Kirk street, Sharpsburg, Pa.
{F. L. White,
A. Smith,
H. J. Glaubitz.

LEVI G STITT, - Master Mechanic, -
For American Sheet Steel Co., Vandergrift, Pa.
h., 152 Franklin avenue, Vandergrift, Pa.
{W. Ginder,
A. H. Beale,
A. Pinkertine.

N. O. STRASBURGER, - Secretary, - { V. Beutner, E. Kaufman, C. C. Wright.
Vulcan Foundry & Machine Co., New Castle. Pa.
h., New Castle, Pa.

C. C. STUTZ, - Assistant Chief Engineer, - { J. Fawell, E. H. Haslam, H. B. Robinson.
Pittsburg Plate Glass Co.,
1625 Frick Building, Pittsburg, Pa.

GEO. A. SUCKFIELD, - Draughtsman, - { M. C. Blest, J. Tesseyman, M. W. Peach.
Pressed Steel Car Co.
1023 Allegheny avenue, Allegheny, Pa.

JAS. E. TATNALL, - Superintendent, - { C. H. Rich, J. M. Camp, C. B. Connelley.
Open Hearth Dept., Clairton Steel Co.
h., Clairton, Pa.

GEO. A. YOUNG, Asst. Engineer of Construction, { R. L. Orr, C. B. Connelley, C. W. Ridinger.
Pressed Steel Car Co.
h., 11 Sipe street, Allegheny, Pa.

It was moved and seconded that the secretary cast the ballot electing the 64 applicants to membership. (Motion carried.)

THE SECRETARY—The Board of Direction have decided not to publish Prof. E. L. Corthell's paper, on Two Years in Argentine as the Consulting Engineer on National Public Works, which was read at a joint meeting of the Academy of Science and the Engineers' Society, as this paper has already appeared in a number of periodicals. If, however, any member desires a copy of this paper he can obtain same from Prof. Corthell, No. 1 Nassau St., N. Y. A copy is also kept on file at the Society's rooms.

THE PRESIDENT—Gentlemen, a good many of those present to-night were at our annual banquet. In the enthusiasm of the moment, we elected Mr. Joseph Ramsey, Jr., president of the Wabash Railroad and one of our honor guests, an honorary member. But upon cooler consideration it appeared that according to the constitution, when you want to elect an honorary member, it is necessary that the name shall be proposed by ten members, in good standing, passed upon by the board of direction, and brought before the society for action. In order to make his election legal it was deemed best to bring it up to-night. In further discussing the matter, it was thought well to propose two other names for honorary membership. One of the names was perhaps inadvertently omitted the night of the banquet. I speak of

Mr. James Dodge, an engineer of standing in his profession and a man we were glad to have with us. Mr. Dodge wrote me a personal letter which I received last week, asking for ordinary membership in our society. I felt very much complimented to have him wish to be a member of our society. At the board meeting it was proposed to elect him to honorary membership. Then there is one of our own members who is one of our ex-presidents and who is known, not only in Pittsburgh, but by all the civilized world, that is Dr. John A. Brashear (Applause). A paper was prepared to this effect, which I will read.

Pittsburg, Pa., March 14, 1903.

We hereby join in proposing the names of the following gentlemen for honorary membership in the Engineers' Society of Western Pennsylvania:

JOSEPH RAMSEY, JR., St. Louis, Mo.
President Wabash Railway.

JAMES M. DODGE, Philadelphia, Pa.,
President Am. Soc. Mech. Eng.,
President Link Belt Eng. Co.

DR. JOHN A. BRASHEAR, Allegheny, Pa.,
Chancellor Western University of Pennsylvania,
Scientist and Instrument Manufacturer.

Chester B. Albree, J. M. Camp, C. B. Connelly, Sam'l. Diescher, S. M. Kintner, C. W. Ridinger, Ralph Albree, Henry W. Fisher, Sumner B. Ely, B. M. Everson.

NOTE—These names were approved by the Board of Direction, Saturday, March 14, 1903.

CHESTER B. ALBREE, President.

These names were passed upon by the board and I now present them to you for election in our society as honorary members. As I cannot personally make the motion, I will ask someone else to make the motion.

MR. ENGSTROM—I move that the secretary be instructed to cast the ballot electing these three gentlemen honorary members of our society. (Motion carried.)

THE PRESIDENT—Gentlemen, as read at the last meeting, a Mechanical Section has been formed in our society and according to the constitution it was necessary to give notice at one regular meeting and vote at the next regular meeting. The Mechanical Section have fulfilled the requirements of our by-laws, adopted a constitution, elected officers of their section, and they have fulfilled the conditions in every way, now all that is necessary is the vote of the society to make them a regular section.

It was moved and seconded that the Mechanical Section be recognized as a regular section of the Engineers' Society of Western Pennsylvania. (Motion carried.)

THE PRESIDENT—We have here the official petition from the Structural Section to become a regular section of our society.

At a regular meeting of the Engineers' Society of Western Pennsylvania, held at the Society's House, 410 Penn Ave., Pittsburg, Pa., on Tuesday evening, February 17, 1903, a committee having been appointed to consider the advisability of forming a Structural Section, and such a section appearing to that committee to be desirable for the pursuit of special study in structural lines. The undersigned members of the society hereby petition the Board of Direction for permission to form the Structural Section of the Engineers' Society of Western Pennsylvania:

E. K. Morse,
J. F. Kuntz,
W. M. Judd,
Willis Whited,
Henry M. Wilson,
F. M. Bowman,
Z. H. Sikes,
D. F. W. Hildner,
James K. Lyons,
P. Brynn,
Andrew L. Ackerman,
Arthur J. White,
Thos. Kunder,
Geo. H. Randall,
Louis Devine,
A. E. Myers,
E. H. Riggs,
J. A. M. Irvine,
Harry Leacock,
G. M. Shaw,
Louis J. Affelder,
R. Khuen, Jr.,
Chas. Worthington,
W. G. Wilkins,
Geo. T. Barnsley,
Chester B. Albree.

This has to come up for preliminary action and for final action at a subsequent meeting. This is simply an announcement

that they have made application, and I would say that both this and the Mechanical Section are now in full operation, and both have had very successful meetings.

The Mechanical Section had a meeting the other night with some 60 or 70 present and had a very good discussion. They expect to have another meeting April 7. The Mechanical Section meets the first Tuesday of every month. The Structural Section meets the last Tuesday of every month. A paper will be presented by Mr. Frank Webster. All members are eligible. There are no extra dues to belong to a section. Furthermore, all members of the society are invited to attend the meetings of any of the sections. They will be gladly received. We hope that these sectional meetings will be the means of bringing a great many men together, and enabling them to accomplish a great deal. In this connection, I would say we have had a communication from our Chemical Section to the effect that the Pittsburgh Branch of the American Chemical Section desires to meet with our Chemical Section, and while we have not yet arranged any exact method to accomplish this, yet it was decided we could invite them to join with us in our meetings. So hereafter, the Pittsburgh Branch of the American Chemical Society will meet with us Thursday evening, the regular meeting of our Chemical Section. Any papers presented, whether presented by our own society or by our guests, will be entitled to publication in our minutes, provided they pass the ordinary regulations. The next meeting will be Thursday evening, March 19.

Some time ago, by a vote of this society, a Department of Employment was to be organized. This department has been organized, and I am rather glad to say we have had far more applications for men than we have had for positions, which would go to show that nearly every man in our society is in a good position. We have demands for architects, field engineers, and all sorts of men. We do not have any applicants for these positions. I wish it understood, at the same time, that if anybody is out of a position it would be well to notify this department, so that we can oblige those who want men, because a great many of those who want men are represented in our society. Up to the present this department has been run by your president. It is quite a little work

and the following committee has been appointed to take care of this department: Mr. Chas. Worthington, chairman, and Mr. Wilson and Mr. H. J. Lewis. Any communications should be sent to the Employment Department of the Engineers' Society, 410 Penn Ave., and will be referred to the correct committee, who will take care of the applications.

At the last meeting a committee was appointed to draw up resolutions on the death of Capt. D. P. Jones. I believe Mr. Ashworth and Mr. Davison were appointed. Are they ready to report?

Pittsburg, Pa., March 17, 1903.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA, CITY.

MR. PRESIDENT — Gentlemen, your committee appointed to adopt resolutions upon the death of Capt. D. P. Jones, a late member of this society, beg leave to offer the following:

Whereas, It has pleased the Creator of this Universe and dispenser of all things, to remove from among us our Associate, Capt. David P. Jones, a member of this society,

Resolved, That in the loss of Capt. Jones, this society is deprived of one of its most active and valuable members. Although comparatively but a short time with us, he proved himself an active and interested member, always looking to the advancement of the Engineering Branches of this Association. His social qualities were such as to bring him close, not only to the members of this society, but to all those with whom he came in daily contact. His almost life service in the United States Navy gave him exceptional opportunities to develop advanced conditions of Marine Engineering. The approval of his fellow officers in the Navy and with all whom he came in relation with afterwards in the walks of daily life, stamped him as a man who became endeared to his fellow men. Ths society therefore gives this token of regret in his loss. In testimony of same, be it

Resolved, That a memorial page be set apart in our printed proceedings and that a copy of same be forwarded to his family.

Respectfully submitted,

D. ASHWORTH,
GEO. S. DAVISON.

THE PRESIDENT—Gentlemen, you have heard the report of the committee. What is your wish in regard to it?

MR. ENGSTROM—I move that this resolution be adopted and entered in our minutes and the committee be discharged with thanks. (Motion carried.)

THE PRESIDENT—At the last meeting, owing to a lack of time, we omitted to receive the reports of committees. However, to-night we will try to make amends and get very short reports. Have the Building Committee anything to report?

MR. DAVISON—We are just to report progress. The society is scarcely large enough to warrant our going ahead.

THE PRESIDENT—There is an old committee to report. That is the Reception Committee of the last year; they have only to report on the banquet, as the new Reception Committee have other matters in charge.

THE PRESIDENT—This brings us up to the new Reception Committee. Mr. Barnsley, have you any announcement to make?

MR. BARNSLEY—The Reception Committee hopes to arrange for a visit to the Frick Building soon. If all arrangements are perfected, that will be an occasion for a very interesting visit, and I will say further, that we will send printed notices. The occasion will wind up with a "Dutch treat."

THE PRESIDENT—Gentlemen, that sounds very attractive. We all know of the Frick Building, and we have also heard of a place called the Union Restaurant, where we can have as good a time as we please.

PROF. KINTNER for the Program Committee—I would like to say that we are prepared with papers for the next meeting, on gas, but for the one following that we are still in need of one or two papers on the subject of pipe-making machines. If there is any one who can give us a good paper on that subject we would be glad to hear from him.

THE PRESIDENT—Gentlemen, I think that finishes the regular business. We have a goodly company here to-night. The subject for discussion to-night is a very important one. It is important to the engineers directly engaged in concrete work and it is important to every kind of an engineer, and not only to every kind of engineer but to every man and woman who lives in the city

of Pittsburg or anywhere else in this country. We are using on our railroads, streets, building work, and in all kinds of construction work—concrete. It is taking the place of stone and brick foundations, in fact, it is taking the place of structural steel and iron work in certain lines. Concrete work is nothing new. It is as old as the old Assyrian civilization. In Rome and all through those old countries of Italy, Sicily, and down in Tunis, we find concrete work. We find concrete work that has stood the test of tens of centuries, concrete work that has been in existence two thousand years and upwards, and is standing to-day. I have seen arches, pavements, foundations, and structures of concrete work that was put in over two thousand years ago and to-day is in good condition. That is good testimony for concrete. It is better as far as time goes than we have for our steel structures. Our papers to-night are on the subject of concrete, starting in with cement, which is the basis of concrete, and dealing with the different phases of the subject.

We are here to-night not as a body of experts on concrete, to tear up everything a man says; we are not going to do as they do in the American Society of Engineers — simply rip a man to pieces; we are here to learn. If a man makes a very bald statement he will of course expect to be called down for it. The men who are to read these papers are men of experience. They are to read the papers to enlighten us, and we hope to learn from these gentlemen a very great deal that will be of great benefit to every one of us.

The first paper will deal with the foundation of concrete work — cement — its manufacture, what it is, and how to test it. I call upon one of our new members, Mr. Armin Schotte, to read his paper.

CEMENT—ITS MANUFACTURE, WHAT IT IS, AND HOW TO TEST IT.

BY ARMIN SCHOTTE.

My part this evening upon the subject of "Concrete," which is before the Society, and which I am to discuss from the viewpoint of the cement manufacture, will be to discuss the cement only.

Realizing that the subject is large and the time limited, and being but one of the three lecturers to-night, I cannot go into the several phases of my subject very exhaustively, but wish you to look upon this paper as a mere skeleton outline of the same, whose various points I hope to be able to elaborate as may be requested by my hearers if interested.

It was John Smeaton, the builder of the famous Eddystone Light House, on the coast of England, who, in 1756, discovered in the case of hydraulic and other lime, that as against all previously accepted theories, the acquisition of hardness under water did not depend upon the hardness of the stone from which it was made.

He had arrived at this conclusion after a long series of experiments.

With the help of the chemistry he knew, he came to the further conclusion that the hydraulicity of the limes varied directly as the amount of clay contained in the rock from which they were burned.

His was the first scientific investigation of the subject on record, the publication of which led to further researches.

It soon became established through the labors of James Parker, that not only the presence of clay in the limestone bore upon the hydraulic properties of the resulting lime, but also the degree of heat employed in the burning. Parker used certain hard nodules found in limestone deposits and established a plant for manufacturing his cement, which he branded "Roman Cement."

The latter part of the 18th and the early part of the 19th century finds many separate investigators in England and France, working along similar lines.

So Monsieur Vicat, a leading French engineer, and General Paisley, an English engineer, succeeded practically simultaneously in arriving at the chemical secret underlying the production of hydraulic mortar; Paisley having even gone so far as to produce a cement from an artificial mixture of limestone and clay, which he burned at a high heat to a clinker and then ground, which was practically the process of manufacture of Portland cement.

Paisley never put his discovery to commercial use, however.

History is silent upon the question as to what series of investigations led, in the year 1813, Joseph Aspdin, a bricklayer, of Leeds, England, and a man of apparently no scientific attainments, to take out the following patent:

"My method of making a cement or artificial stone for stuccoing buildings, water works, cisterns, or any other purpose to which it may be applicable (and which I call Portland cement) is as follows: I take a specified quantity of limestone, such as that generally used for making or repairing roads, after it is reduced to a puddle or powder; but if I cannot procure a sufficient quantity of the above from the roads, I obtain the limestone itself, and I cause the puddle or powder, or the limestone, as the case may be, to be calcined. I then take a specific quantity of argillaceous earth or clay and mix them with water to a state approaching impalpability, either by manual labour or machinery. After this proceeding I put the above mixture into a slip pan for evaporation by the heat or by the sun or by submitting it to the action of fire or steam conveyed in flues or pipes under or near the pan, until the water is entirely evaporated. Then I break the said mixture into suitable lumps and calcine it then in a furnace similar to a lime kiln, till the carbonic acid is entirely expelled. The mixture so calcined is to be ground, beat or rolled to a fine powder and is then in a fit state for making cement or artificial stone. This powder is to be mixed with a sufficient quantity of water to bring it into the consistency of mortar, and thus applied to the purpose wanted."

He gave to this product the name "Portland Cement," because

of its resemblance when set to the well known Portland building stone, which was very much used in London.

Aspdin, who started a small works, and put his cement in competition with Parker's so-called "Roman Cement," which was considered the best at that time, may therefore be considered the father of the Portland cement industry.

Having arrived now with this short historical sketch at the establishment of the Portland cement industry, which grew with leaps and bounds, and whose product soon outclassed all its competitors in quality, it will be necessary for the further understanding of the subject to give some description of the difference between natural and Portland cement, their method of manufacture and the materials used.

Natural cements have been made from time immemorial.

The rocks from which they are made are argillaceous limestones, either crystalline or laminated, and also more or less dolomitic, that is they contain besides carbonate of lime also varying quantities of carbonate of magnesia.

The composition of these rocks are as varied as the brands under which the resultant products are marketed, and it naturally follows that the physical properties possessed must vary within very wide limits.

The better grades of our Rosendale cements contain approximately from 30-60 per cent. of lime and magnesia, and from 40-70 per cent. of clay, containing silica, alumina and iron oxide.

Such suitable raw materials are found in great abundance at many points in the United States, and great quantities of cement are made from them in open kilns, similar to lime kilns.

The rock and fuel, either coal or coke, is put into the kiln in alternate layers, then fired and the burned material drawn off at the bottom, while the new is added at the top. In fact the process is exactly similar to that of burning ordinary lime.

The burned material is then taken and ground to a fine powder, in which form it is packed and marketed.

Pure burned lime has great avidity for water and lumps when wetted, immediately start to slack, developing much heat during the process, which is finished in about fifteen to thirty minutes.

The volume of the slacked lime is also practically three times the raw.

Although the hydraulicity of the lime is increased proportionately (up to certain limits) with the amount of argillaceous matter contained, yet its avidity to take up the water necessary for slacking is proportionately decreased by it, as is also the ratio of the increase of volume after slacking.

In some cases the burned stone in lump is practically not effected when wetted, and our best natural cements are fairly constant in volume.

It will be seen, therefore, why cement must be ground in order to be fit for use.

Natural cements, it will be easily recognized, depend entirely for their qualities upon the nature of the rock from which they are made. The varied composition of the rocks and the low heat at which they are burned, do not easily permit of such handling as to permit bringing the ingredients into intimate and advantageous chemical union.

With a more thorough and scientific method better results could no doubt be obtained.

This has been proven in the manufacture of Portland cement, a product representing in its present state of perfection a combination of the highest technical skill, chemical and mechanical.

Portland cement is an entirely artificial product, composed of lime, silica, alumina and oxide of iron in certain combinations. Investigations extending over many years and made by men most eminent in their profession, with all facilities furnished them by such powerful combinations as the Association of German Portland Cement Manufacturers, to instance only one of them, has proven that the best results are obtained when these ingredients are combined in approximately the following formula: 10 (Si O2 Al2 O3) 2O Ca O, which means that Portland cement is composed of trisilicate and bi-aluminate of lime (part of the bi-aluminate of lime is in Commercial Portland Cements, displaced by some biferrate).

Recent experiments by S. Newberry and others have proven that trislicate of lime alone does not possess hydraulic properties when mixed with water, but that such proportions of the in-

gredients as are represented by the above formula are necessary for the chemical re-arrangement which takes place when water is added and the mass hardens.

Portland cement being produced from an artificial mixture, it would seem that the sources from which the raw materials for its manufacture may be drawn were not limited to the same extent as is the case in natural cements.

Theoretically this is so, but actually the limitations surrounding the establishment of a successful Portland cement works are many, for no matter what the good qualities of a product might be, its commercial success depends very much upon its price, not of course taken by itself, but in comparison with the qualities and price of its most efficient substitute.

Most Portland cement to-day is made of carbonate of lime and clay taken from such sources as found in nature and containing, besides lime, silica, alumina, oxide of iron, which are necessary for its proper compounding, also impurities, principally magnesia, sulphur and alkalies.

The process consists essentially of grinding these raw materials together, burning and then re-grinding them.

It is never the case that in the raw materials as found in nature the lime, silica, alumina or oxide of iron exist in such proportion as to combine entirely into a product conforming to the above mentioned formula, but in the finished material there exists, beside the trisilicate and bi-aluminate of lime, a certain residue made up in the first place by the impurities already existent in the rocks, and in the second place by the excess lime, silica and alumina, which for various reasons have not gone into proper combination with each other, but all or part of them may have even combined among themselves into other compounds, which may have either a neutral or a harmful effect upon the cement.

Accepted standards and tests derived from long experience have enabled the chemist to tell very closely whether certain raw materials may be combined into a successful commercial cement. As a rule a clay or a shale whose proportion of silica to alumina, plus oxide of iron is over two to one, but not greater than four to one, may be combined with a good marl or limerock.

Without going into details of the relative proportions of lime, silica, alumina and iron required for a good Portland cement, and the quantities of the several minerals used, it must be said that the physical properties of the rocks and their proportions to each other, and the sources from which they are drawn have an important bearing upon the cost of production of the cement.

For the manufacture of Portland cement but two methods are in successful commercial operation to-day, called respectively the wet and dry process, in America. The materials used in the wet process are invariably wet marl and clay. Otherwise the dry process is employed. In the wet process the marl, a carbonate of lime of but recent geological formation, is taken from the swamp or lake where it occurs, by means of a suitable dredge. It then passes through a squeezer, which holds back all foreign matter, such as pebbles, roots, etc., and allows only the marl to pass through screens provided for the purpose.

The proper proportion of clay is then added to the batch, which is then thorughly mixed in a wet pan, or in a mixing and grinding mill constructed for the purpose. After considerable water has been added the resulting slurry is run into vats or backs which are kept constantly agitated. The effect of this agitation is not only a thorough mixing, but also by this means when the liquid is drawn off into another back provided for settling purposes, only those particles of minerals fine enough to float are carried over, while the coarse and unfit remain. From back No. 2 the slurry, which contains about 40 to 60 per cent. of water, is pumped or drawn into rotary kilns. The materials for the dry process are run from the quary or mine in crushers or rolls, and reduced there to the size of a walnut. This material, after the proper mixtures have ben made, is further reduced by various grinding machinery to a powder of such fineness that at least 75 per cent. passes through a one-hundred mesh sieve. This powder is then fed into the rotary kiln and burned. The resulting clinker in both cases is then re-ground into the cement of commerce.

The mixer and grinder usually employed for preparing slurry is called a wet tube mill. It is essentially a horizontal steel cylinder about 20 feet long and 4 feet in diameter, half filled with

flint pebbles as large as a hen egg, running upon suitable gear and lined with wood.

The same mill, only lined with chilled steel, is used for fine grinding, either of the stone in the dry process, or the clinker after it is burned.

In the dry process various other mills are also used, such as the Smith Hammner Mill, the Griffin and Sturtevant Mill.

These mills as a rule are not capable of reducing material which is larger than a given size, and in such cases a preliminary reduction by means of rolls or ball mills is necessary.

The backbone of our cement industry is undoubtedly the rotary kiln employed for burning the raw material to a clinker. It is a long steel cylinder about 60 feet long and 6 feet in diameter, placed horizontally with a slight incline. As its name implies, it slowly revolves.

This cylinder is lined with a high grade of aluminate fire-brick.

At the higher end, which terminates into a stack, the raw material is fed into it by means of a spiral conveyor and a water-jacketed trough from a storage bin, whose rate of outlet can be automatically or arbitrarily regulated.

The slight inclination from the horizontal and the rate of rotation determines the time consumed by the raw material to travel through the kiln.

Into the lower end, which is protected by a shield, leads a tube, through which powdered coal is blown by means of air from a fan.

The coal is ignited and roars through the slowly revolving kiln in a flame 20 to 40 feet long, heating the inside to a white incondescence.

While the operations in all parts of a Portland cement mill are interesting to the technical man, the kiln room, with its dozen or twenty hot giants groaning and sweating under their work throwing out golden pebbles to be picked up by eager conveyors, is a sight which in its attractiveness, especially at night, can only be compared to a Bessemer converter in full blast, or the stream of metal spouting from a furnace.

This rotary kiln was invented by Ransome, the originator of the concrete steel construction, which bears his name, and first tried by him in England. After repeated failures there were several unsuccessful trials here the process was finally perfected, especially with the financial assistance of Mr. Whittaker, whose works near Easton were the beginning of the present plants of the Alpha Portland Cement Company. Although not so economical in fuel consumption as other kilns used in the business abroad, the continuous feature of this kiln enabled the installation of a continuous method manufacture, almost automatic and requiring but little skilled labor in the process, thus more than overbalancing the others, economy of fuel.

After the cement is ground it is taken to the storehouse to allow it to season.

The effect of seasoning is to improve its quality by air slacking the free lime, whose tendency to treble its volume during the process I have alluded to in another part of my paper, and which on that account would certainly not effect favorably that desirable quality of all good Portland cements, namely, "constancy of volume."

Seasoning or ageing also tends to make the cement set more slowly.

It would be too lengthy to make a comparison of even a few of the natural cements with Portland cement, so I will rather point out briefly now in what manner Portland cement is acted upon by some of the substances it frequently comes in contact with.

Hard water contain sulphate especially, increases the final set, but does not affect the strength. Sea water due to presence of chloride of magnesium and sulphate of magnesia increases the setting time, but impairs final strength.

Strong acids dissolve Portland cement.

Carbonic acid acts only in the presence of moisture on it.

Moisture, of course, acts upon it.

Ordinary alkalies, tar and mineral oils have no influence. Fatty oils, tannic acids, even sour malted liquors act detrimentally.

Ordinary changes in temperature are not injurious, nor do they affect the set, provided the water employed is not allowed either to freeze or evaporate too rapidly.

Boiling water does not affect Portland cement which has set.

Cement hardens in warm water faster than in cold.

The hardness is affected detrimentally by very hot water, but water above boiling point, yet water as hot as 200-300 C. is not yet dangerous.

A paper on "Cement" would not be complete without a description of the ordinary tests required by determining its quality.

These tests are of two kinds. The "chemical" and the "physical."

According to the first a fair average analysis is represented by the following table:

Lime	63.02
Silica	21.58
Alumina	6.52
Ferric Oxide	2.82
Magnesia	1.13
Alkalies	2.27
Sulphur	1.15
Residue	1.51
	100.00

The first physical test is made on a set of briquets of standard pattern, whose smallest section contains one square inch.

These briquets are tested for tension, after being allowed to age for various periods.

Some of these briquets are of neat cement and others are mixed with several times their weight of sand.

Compression tests are made on cubes and according to a similar scheme.

A standard sand is prescribed.

A boiling test is also usually required.

For this a test pat 4 in diameter and $\frac{1}{2}$ thick at the center is prescribed.

This pat, which is placed upon the glass, is allowed to become one day old, and is then placed in boiling water for a given time. Pats of good cement remain intact.

A similar pat exposed to the air should not show hair checks.

A thin glass cylinder is filled with wet cement, and, as this test is intended to show constancy of volume, the mass should neither crack the glass nor shrink away from it.

Specific gravity of Portland cement should be about 3.2.

THE PRESIDENT — Gentlemen, you have heard a paper telling us how cement is prepared, and dealing at the end of the paper with testing cement. We expected to have had a paper to-night dealing with the subject of testing cement, at greater length, by Mr. Bell of the Pittsburg Testing Laboratory. Unfortunately he has been compelled to be out of town, and telephoned me yesterday afternoon that it would be impossible for him to do justice to the subject in so short a time. He hopes to be able to give us a paper on the subject, and bring down a new machine they have for testing cement. At some future occasion I hope we will have that paper.

THE PRESIDENT — Gentlemen, I have a little note here which says that Mr. T. P. Roberts, who is very well known to all of us, has a paper on concrete for us. This we did not know in time to announce in our bulletin. If Mr. Roberts is ready with his paper we are certainly ready for him.

MR. ROBERTS — Mr. President and fellow members, I touch here only on one point on concrete which I thought might be of interest to some of our members — the water tightness of concrete.

WATER TIGHTNESS IN CONCRETE.

BY THOS. P. ROBERTS.

Concrete foundations of buildings, wheel pits, and other works below the flood planes of adjoining rivers, though built as they generally are with special reference to water tightness, are frequently found to leak, or at least to flush with dampness, under the strain of only a few feet pressure.

Concrete powder magazines set in hillsides, or behind the esplanades of coast fortifications, are notably hard to keep dry. An instance is recently cited of a magazine, when there was occasion to dig a ditch $2\frac{1}{2}$ feet deep, outside the concrete, which ditch being suddenly filled during a rainstorm, leaked through 30 feet of concrete rather than through the sandy loam soil of the esplanade, which descended seaward with a considerable slope. The water in two days coming through the roof of the magazine, which was ten feet below the bottom of the ditch and, as before said, distant

from it thirty feet. There are engineers, however, who prescribe 1-2-4 concrete in a layer of a few inches thick, in the bottom of extensive reservoirs, to make them water tight.

True, this concrete is usually laid over a course of from one to three feet of clay puddle. It is the writer's opinion that while many concrete lined reservoirs have proved to be impervious, the credit for their tightness is due, in most cases, to the puddle. The specifications usually provide in reservoir work, that the mortar should be composed of 1 cement to 2 sand, and sufficient of this mixture to be used to fill the void in the gravel or broken stone whichever is used.

Experiments conducted about a year ago at the Thayer School of Engineering on the permeability of concrete under hydrostatic pressure, gave the following general results:

First. With mortar, 1 part cement to 2 parts sand (ranging from 30 to 45 per cent. of the concrete), at 80 lb. pressure, at the end of two hours the concrete, 5 inches thick, 11 specimens leaked, 7 specimens did not leak.

Second. With same proportions and time under 40 lb. pressure, 5 specimens leaked, 7 specimens did not leak.

Third. With same proportions and time under 20 lb. pressure, 4 specimens leaked, or all that were tried. The fineness and other particulars, which should be known regarding the cements used in their series of tests, were not given in the published reports, though it was stated that cements were of standard brands. Rather curiously, the one brand, furnished by the manufacturers as being specially adapted for making water tight concrete, gave the poorest results.

About all that can be said of tests of this sort is that the permeability of concrete depends altogether on the fineness of the cement, and the degree to which the voids in the sand are filled with it. Of the 14 tests, at the Thayer School, made with the same grades of cement, where the mixture was one cement to one sand, none of them leaked.

The engineers and the inspectors are extremely careful in making tests of the setting qualities and tensile strength of the cement they use, but considering the vast amount of published information in regard to the use of cement, it is remarkable that

so little has been written on the subject of water tightness in concrete.

No doubt the military engineer, when he dug the ditch outside the massive concrete fortification, never dreamed that the rain would fill it, or if it did that the water would leak through the concrete in preference to going through a few feet of sandy loam. Why, we may ask, was the sandy loam more water tight than the concrete? The answer is simply that the loam contained more fine particles of cement to fill the voids in the sand than there were fine particles of cement to fill the voids in the concrete mortar used in making the concrete.

The visual test is alone used by inspectors in determining whether the voids in the concrete are filled, yet it may be demonstrated that, with an absolutely impervious mortar, a water tight concrete may be made in which there may be many and easily discernible voids, and contrawise there is such a thing as filling all the visible voids in the gravel, even having a surplus of mortar, and yet discover that the concrete will leak. It is apparent, therefore, that we should be concerned, where water tightness is important, with the voids in the sand and in the fineness of the cement used for filling them. A good idea may be formed of the comparative void filling capacity of cement and clay, by trying samples of each which have passed through sieves of standard mesh, and noting the time of the deposition of equal volumes in water at given intervals, until the point of clarification is reached. While the writer is not aware that any such tests have been made, he believes that clay can be found of red, blue, and so-called yellow, or any other natural colors from veins in our hillsides that will win out in such a test every time. The sp. gravities of clay and Portland cement are not materially different, so the suggested test would show their relative degree of fineness. It is to the minuteness of the particles used in filling the voids in the sand, that the imperviousness of the concrete is due.

The question might also be raised as to whether the chemical combination of cement and sand, with the result of the formation of silicates, may not be productive of voids, possibly very minute, but so interwoven as to form a connected tissue of voids through which water may percolate under pressure.

It is very often the case that muddy water rising about concrete, masses, sufficiently rapidly to develop pressure, will force clay particles into the cement and seal them water tight, sometimes permanently, and sometimes not, for with the subsidence of the water, the retained clear water in the concrete may exert a sufficient "back" pressure to drive out the mud particles previously deposited over the surface of the concrete.

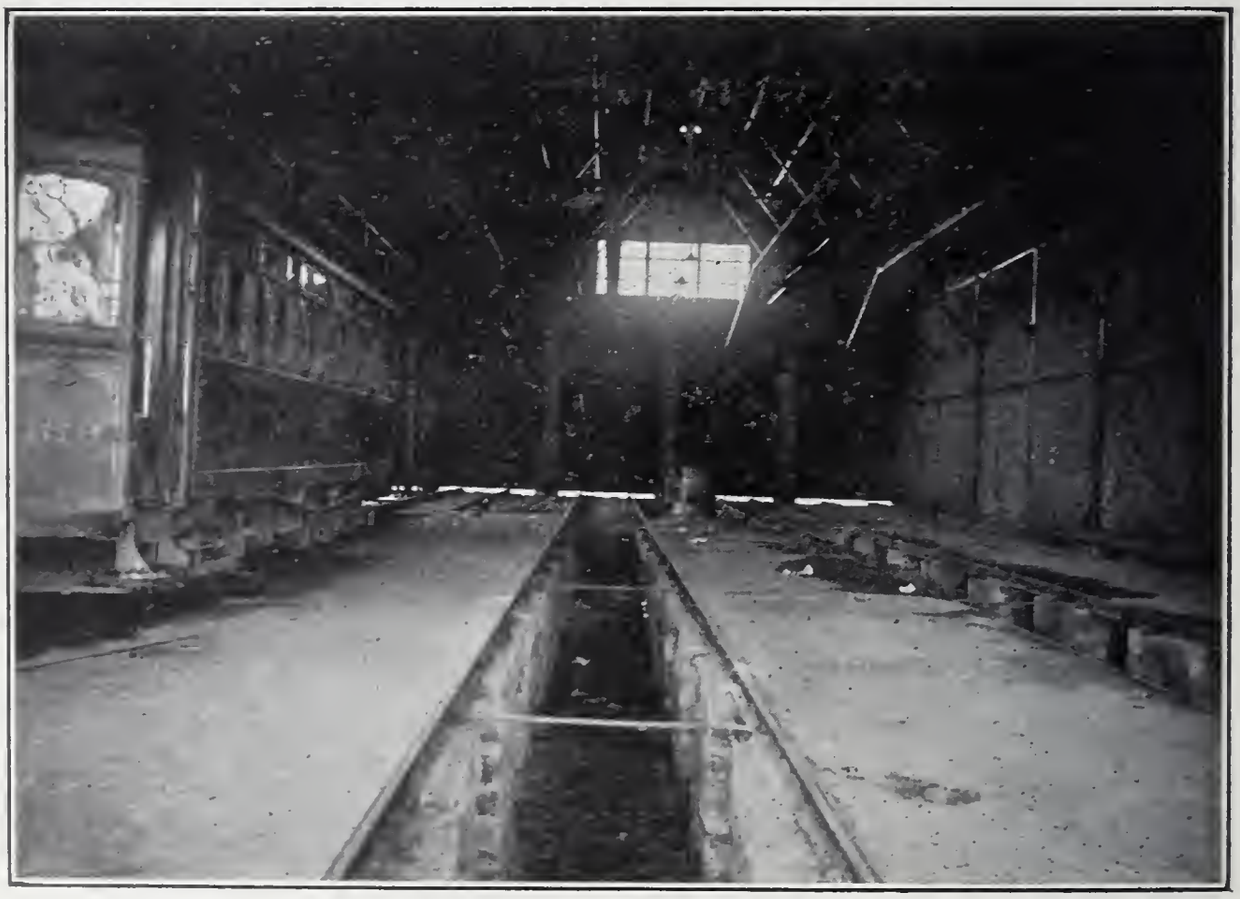
Concrete is coming into vogue extensively in all kinds of work, both above and below water, but so far as the writer's observation extends, little or no difference is made either in the composition or in the method of placing concrete which is expected to stand hydrostatic strains and the action of frost and that which will not be exposed to such strains. We have in Western Pennsylvania examples of exceedingly hard grey, and bluish colored sandstone of great tensile strength, and of close texture which nevertheless crumble and disintegrate in a few years' exposure to the action of moisture and frost. Then we have a coarse-grained, yellow-brown stone, in the Beaver Valley, of little tensile strength when quarried, which withstands the action of moisture and frost without disintegration, and it is reasonable to believe that we may find the same unexpected differences in the durability of cements.

A Russian engineer, who recently visited Pittsburgh, remarked in the presence of the writer that he had traveled extensively through Germany, England, Canada and the United States, and everywhere his professional brethren pointed out to him their wonderful concrete constructions, but he said the Russian engineers were holding back their approval, waiting for the test of time, which alone would determine the durability of concrete, especially of concrete in peculiarly exposed situations.

The Russian may be right in part, and the writer believes he is, in questioning the durability of concrete exposed to the action of water and frost, and which concrete is not in itself water tight. It might be well to consider the expediency either of constructing cores in concrete walls of some really impervious material, or covering their surfaces in such manner as to keep the water out, leaving "weep holes" so to speak, below the frost line for retained water to escape. That Russian engineer may return to America

a few years hence, and it would be peculiarly grating to hear him say, "Didn't I tell you so?"

We had expected to have to-night a paper of very great value by Mr. Edwin Thatcher, the well-known authority on concrete. I saw Mr. Thatcher in New York, and I found him to be an extremely busy man, and engaged in a controversy with some other men on re-inforced concrete. He was saving his fire for that, and even if he had time was unwilling to give us a paper just at the present time. However, we have a short paper to-night upon re-inforced concrete by Mr. G. M. Scofield, who was associated with Mr. Thatcher. He could not be here to-night and Prof. Kintner has kindly consented to read the paper. I would say that this paper of Mr. Scofield's does not deal with the general subject of steel and concrete construction, but with a particular example of it, the case of the Youngstown car barn, where they put in a floor of re-enforced concrete.



Concrete Steel Floors.
Car Barn of Pennsylvania & Mahoning Valley Railway,
East Hazleton, Ohio.

A RE-ENFORCED CONCRETE FLOOR USED IN THE YOUNGSTOWN CAR BARN.

BY G. M. SCOFIELD.

The car barn was built for the Mahoning Valley Railway Company by The G. M. Scofield Co. The concrete steel floor is used between the tracks over the track pits, which are thus kept open over the entire space instead of between the rails only, as is the usual practice. By this method, workmen are free to pass from one track to another without climbing up to the floor level and down again; the space for working is more than doubled; and ample space is provided for lighting wires and heater pipes without encroaching on the working space in the pit proper.

The rails used were 85 lb. A. S. C. E. section 5 inches high. They are supported on masonry piers spaced 10 feet apart and each 5 feet long by 1 foot thick, thus leaving 5 feet open space every 10 feet. The piers were built to approximately the level of the bottom of the rail whereupon the rails were placed in position, properly aligned and brought to correct surface with wooden wedges. Strips of $\frac{3}{4}$x$\frac{3}{4}$-inch wire netting were then placed under the rails over each pier and the space grouted with 1 to 1 mortar. Considerable difficulty was experienced in getting the thin opening under the rails properly filled with mortar, and I am convinced that it would have been wiser to allow a space of 1 inch under all rails.

There was no anchoring of the rails to the piers, but the adjacent rails of each pair of tracks were joined every 5 feet with a $\frac{3}{4}$ O bar with two nuts at each end.

The centering was made of 2-inch planks which had been used for falsework on the building, supported every 5 feet on 2x8 joist suspended to the rails by $\frac{5}{8}$-inch diameter hook bolts. These joists were of hemlock, and considerable trouble was caused by the breaking of cross grained pieces.

After the centering was in place, a layer of 1-3 Atlas cement mortar was placed, then $\frac{1}{2}$-inch O "Thacher Pat." rods were laid

6 inches apart transversely with the ends extending over the flanges of the 5-inch rails, then $3\frac{1}{2}$-inches "Thacher Pat." bars were laid longitudinally one in the center of the span and one 6 inches from each rail. These longitudinal bars were placed in 22 feet lengths overlapping each other 2 feet. They are not required for strength but give an added toughness and an increased factor of safety to the floor by distributing a given load over a larger section of floor. It was at first intended to place these longitudinal rods beneath the $\frac{3}{4}$-inch cross spacing bolts above referred to, but this was found so difficult in practice that they were finally laid *over* the $\frac{3}{4}$ O bolts and bent down on each side to the level of the top of the $\frac{1}{2}$-inch transverse rods by standing with one foot each side of the cross bolt, the peculiar shape of the "Thacher" rod making it comparatively easy to bend them in this way.

After the rods were placed, the space between the rails was filled with 1-2-4 Atlas cement concrete, using $\frac{3}{4}$-inch crushed limestone. This was tamped down and the surface covered with 1-2 Atlas mortar and troweled to proper grade.

The concrete used for this floor was much richer than was necessary, but it was thought best to use this mixture in order to get the work out of the way of the frost, and also have it ready for use as soon after placing as possible. The temperature went as low as 6 degrees below zero while the floor was being placed, and the barn was heated with four 36-inch rings filled with coke, as well as several small coke fires on improvised grates.

The centering was removed after the floor had been in place 20 days. It was found that the 2x8 rough hemlock plank used for centering had sufficient adhesion to the concrete to hold them in place, so that the joist were all removed and then the plank were taken out one at a time by tapping them gently with a hammer.

The spans covered by the floor are 7 feet 6 inches in one half the barn and 9 feet in the other half, measuring from center to center of rails. The thickness was $4\frac{3}{4}$ inches at rails and 5 inches at center.

The floor was intended to have a safe load capacity (exclusive of its own weight) of 115 lbs. on 9 feet span, with 1-3-6 con-

crete 6 months old, with factor of safety of 4. With the richer concrete used, it should have a strength of 115 lbs. for 9 feet span and 135 lbs. for 7½ feet span in 30 days' time.

The rods were spaced with a 12-foot pole with saw cuts every 6 inches, as it was found impossible to get accurate spacing without some such assistance to the eye. With the bars on the same level as the floor, one boy can place all bars for from 2,000 to 4,000 square feet of floor per day of nine hours.

The car barn is a fire proof structure 170 feet long and 185 feet wide, but the track pits do not cover the entire floor.

DISCUSSION.

MR. ALBREE — I would say that there are various kinds of bars used in re-enforced concrete work. The commonest bar is the ordinary round bar. Several inventors have gotten up special forms of bars to be imbedded in concrete. The well-known Ransom twisted bar has given excellent results. Another bar made in St. Louis consists of a square with a system of corrugations extending around it. Mr. Thatcher, with whom Mr. Schofield has been intimately related, has gotten up the Thatcher Bar which he claims is better, and some samples of which are here.

We have with us to-night Mr. Cummings, a civil engineer, and contractor of Pittsburg, who is one of our new members and who is thoroughly conversant with re-inforced concrete work. He has had considerable experience in this line, and we would ask him to favor us with a word or two about it.

MR. CUMMINGS — Gentlemen, I want to say that I have come unprepared to talk on this subject. I am particularly interested in it, however, as I am identified with Mr. Thatcher. I might say also that I represent Mr. Thatcher in this district and after awhile I will be glad to talk with you about the sale of the bar, following the lines of our friends. As a matter of fact I would like to pass these samples around as they will exhibit in a practical way more than I can tell you in a few words. The distinctive features of the Thatcher bar are that it is flattened out at intervals, forming mechanical adhesion. The object of this is to prevent slipping. It has been found among certain engineers

who have investigated the subject that when round bars are placed under great stress, they slip, and various systems have been devised to utilize the full strength of the bar, but they involve a great number of wires or strips or whatever you please to call them, and other things that are in the way, from a practical standpoint, in building structures. The Thatcher bar, however, is a distinct advance in the development of this application of steel bars and concrete, and I will go to the blackboard and show you why. (Mr. Cummings drew several illustrations on the board showing the difference between the Thatcher bar and others.) The Thatcher bar has been found, by experiments and tests, never to slip. It has also been found that it does not affect the concrete. What I mean by that, is that a square bar placed in the same position produces incipient fracture. That is one reason why Mr. Thatcher has adopted the round bar for his work. Now the application of this bar is as simple as anything can be. Simply imbed the bar in ordinary concrete. The bar is placed so as to take all the tensile strain. Mr. Thatcher has covered that recently in the "Engineering News," copies of which I have here with me, and will be glad to give them to anyone who is interested.

It was my good fortune, as contractor last year, to make a proposition to build a retaining wall for one of the railroads. It was an ordinary section of wall. (Draws section of wall on blackboard.) I made the proposition to the railroad company to build this wall at so much per cubic yard. We will say the contract was $24,000.00. I also accompanied my proposition with a design of the concrete and steel retaining wall. I proposed to build the retaining wall, and guaranteed that the concrete would not crack. I will show you the design, practically, of my wall. This wall is approximately eight to fifteen feet high, but to meet any questions in the mind of the engineers, I would suggest that it be six inches thick at the base and every six feet counter-enforced. Now within this six inches were imbedded Thatcher bars at the proper distances. (Draws section on blackboard.) One thing that I want to point out is that there is a street up here above it. Of course it required a very heavy wall to withstand that. The application of concrete steel work to structures to-day is one of the transitional states that we are passing through, and we do not

know it. I will mention another object to you. It was my fortune last year to finish a contract within thirty miles of Pittsburg, in which I used a concrete caisson, and sunk it successfully with a concrete cutting edge. (Draws section on the board.) That is, it was sunk successfully in the neighborhood of thirty feet, and I want to tell you there was no crack in the structure. I think that will tell you what can be done with concrete with careful work. A gentleman has spoken to-night of the water tightness of concrete. I have a contract of that kind now. A water tank is to hold 50,000 gallons, 27½ feet in diameter, 16 feet high, and containing a little more than 50,000 gallons. That tank is expected to be constructed with Thatcher bars, imbedded in concrete. It will be six inches thick at the top and nine inches at the bottom. (Shows section of tank on the board.) Inasmuch as there is nothing else going into it, we expect to make that concrete water tight. I want to say to you, gentlemen, in regard to practice in Europe, they do their concrete work very carefully, and it requires very careful manipulation to secure good results. That is one of the most essential things about concrete work — that the application shall be carefully done. Another thing they do not use sand that is in the slightest degree dirty. You cannot make good concrete unless you have clean material to work with. The chemical action between the cement and the other materials is necessary to make concrete. They are prevented when you use inferior material. The way we expect to make this tank water tight is to use what the French people call the glasse' finish. The best illustration I can give you is the pavement in front of the Union Depot in this city. That is the kind of finish we expect to give to make it water tight. There is a concrete water tank at Hazelton that has been in operation for three or four years. It was shown to me by Mr. Diddier. I think it is an exceptional illustration of what can be done with concrete.

A MEMBER — What proportion of concrete is that?

MR. CUMMINGS — It is about two to four. That is about the standard.

A MEMBER — Did you ever try asphaltum?

MR. CUMMINGS — The use of asphaltum is all right except under great pressure. I made a little inquiry about its results. I

see no necessity for using asphaltum or any other compositions, especially if you have good mechanics that thoroughly understand their business. Now I want to show you one other thing, and that is concrete steel piles. It may seem absurd to you to use concrete steel piles, but my confidence is such that I am just about entering into a contract to drive 1,200 on the sea coast. These are driven like the ordinary wooden pile with a pile hammer. Of course in speaking of concrete work, I am referring entirely to re-enforced concrete. In the piles are imbedded Thatcher bars, and in that connection one of the most valuable articles I have read has been translated in the "Engineering Record," February issue. I am sure it will be worth while to read those articles. In one place there, it tells about a bar which has been bent in the form of a letter "S," without any effect whatever upon the concrete. I myself saw within the last two months concrete steel trolley poles. That is carrying concrete right home to us. I want to show you an experiment that was conducted on that trolley pole. (Makes sketch on board.) At this point there was suspended 2,500 pounds from a pulley, 20 feet high; that pole was pulled out of the vertical very nearly two feet, and it went back to its position again.

A MEMBER — What is the diameter of the pole?

MR. CUMMINGS — About six inches at the top. This all only goes to show what can be done by proper application of concrete steel. I have been a little astonished myself. I would like to tell you something else, but I am afraid you would hardly believe me.

A MEMBER — What shape were those piles?

MR. CUMMINGS — They were square.

A MEMBER — How many rods were through them?

MR. CUMMINGS — Four rods. Two designs were submitted and it is probable that we will use both to find out which is the better plan. The other plan involves some patents of mine and I don't care to talk about those just now.

A MEMBER — How long were the piles?

MR. CUMMINGS — Thirty to fifty feet. They are expected to be constructed vertically. It is thought to be an advantage to construct them that way. We expect to use a hammer four times the weight of the pile with a small drop. We use a sand cushion

like a cup. On that we generally put some lead, something like we do with the ordinary wooden pile.

A MEMBER—How old must they be?

MR. CUMMINGS — About thirty days. As to the adhesion, from an engineering standpoint, there is no question that cement does adhere. The French people have adopted 570 pounds as a basis of their designs.

A MEMBER — To what does that 570 pounds apply?

MR. CUMMINGS — Per square inch; it runs from 250 to 570, but is a very uncertain quantity. Mr. Thatcher is probably one of the most conservative men that it has been my good fortune to be thrown with. Of course, we are all very enthusiastic over concrete steel work. The advantages of the bar which I first intended to explain is on account of its strength, which has been maintained throughout. There is no increase of material. The corrugated bar is a bar of a great deal of merit. It forms mechanical adhesion at the expense of that much metal. It does not add anything to the adhesion. To-day I told a certain firm in this city that if they would construct a certain building entirely of concrete I thought I could do it cheaper than the steel men. That is a great deal to say in Pittsburg. To illustrate, I will tell you an experience I had last July, in regard to a concrete steel bridge at Dayton, Ohio. Mr. Thatcher designed a bridge which is a most remarkable structure, consisting of ten arches with a rise of 1-10 to the span. Bids were asked upon steel bridge, concrete and stone. To sum it all up, a concrete steel bridge was built and for no other reason than that they beat the steel man 25 per cent. in price. In addition to that we cut the time for delivery one-third. This was last July. That bridge has been in operation for some time. It was built in less than one-half the time the steel man talked of delivering the material. I want to point out to you that concrete steel is an economical material for engineers to use, simply because you can calculate concrete just as correctly as a wooden or steel structure and with as good results. I saw a concrete steel beam carrying 100,000 pounds under test. It goes to show that it is not a fad. It has come to stay. I think it is only in a transitional state. I think it is going to finally take the

place of other material to a great extent. There is a fifteen-story building going up in Cincinnati, built of concrete steel.

THE PRESIDENT — It is a real satisfaction to hear from a man who knows whereof he is talking. We have had that pleasure.

Mr. Shinn, have you something to say about cement and concrete?

MR. SHINN — It is something of a surprise to be called upon for an address at my first appearance before the Society. I had not prepared myself to say anything. I will give you some idea, however, of the advancement in concrete work as shown by the manufacture of Portland cement in this country. In the winter of 1874, the Edgar Thomson Steel Works were under construction, and for the foundations of their works there was placed the first order of one thousand barrels in amount that was ever placed in the United States by other than the Government, and the placing of that order persuaded the importers, of which there was only a small number at Boston, New York, Philadelphia, and Baltimore, that there was an inquiry for 5,000 barrels of cement. It thereby had a reverse effect — instead of bringing them into competition, it caused them to try to draw upon one another, and no one had the amount required to fill that order of 1,000 barrels. In 1875, or more correctly 1876, the first Portland cement was made in this country, and there was probably 40,000 barrels manufactured that year. Last year's statistics showed a manufacture of over twelve million barrels, and I do not know of any manufacture that has proceeded more rapidly, and particularly in the last ten years, by leaps and bounds, than that of Portland cement. It has come into a great many uses, as the gentleman has shown, which were never dreamed of ten years ago. The manufacture of common cement has slightly decreased during the last two years, while the Portland has increased at the rate of 50 per cent. a year, from 1900 to 1902 inclusive — that is 50 per cent. each year. Those figures give an idea of the present value of Portland cement as a building material, and possibly an idea of the future, but probably a very faint idea.

THE PRESIDENT — I believe Mr. Smith has a word or two on the subject.

CONCRETE.

BY ACHESON SMITH.

Concrete has become such a factor in masonry work and as a consequence there has been so much written upon the subject that it is rather difficult, within the limits of a short paper, to give anything new. Each one of the great variety of ways in which it is now used is worthy of a special discussion.

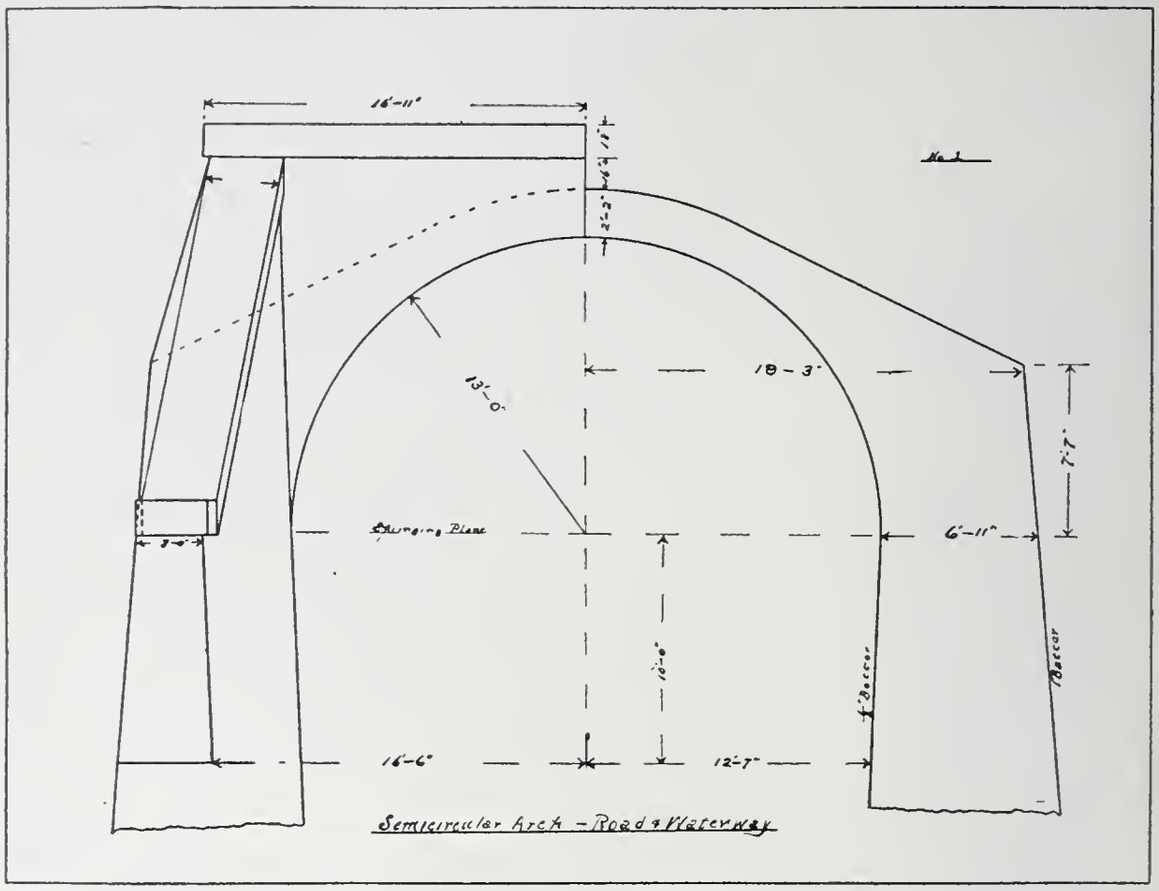
One of the most important uses of concrete construction, particularly to railroads, is the arch. Unreinforced concrete arches have been built of about the same dimensions as those of stone, at about one-half the cost, which are giving perfect satisfaction. Many railroads are using concrete for all their masonry structures, such as road-way arches, arch culverts, tunnel linings, retaining walls, large abutments, piers, etc.

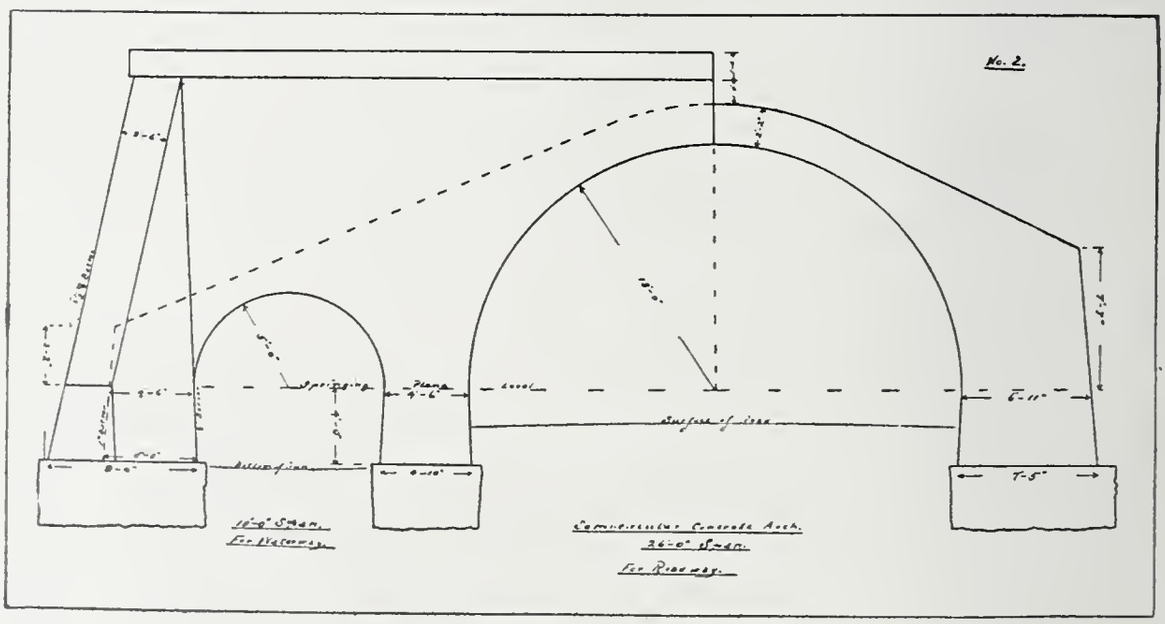
I have here sectional views of several concrete arches which have been built in this district. The first three were built under the direction of Mr. E. C. Brown on the Union Railroad, and are splendid examples of this kind of masonry. The cost of these arches, per cubic yard, was as follows:

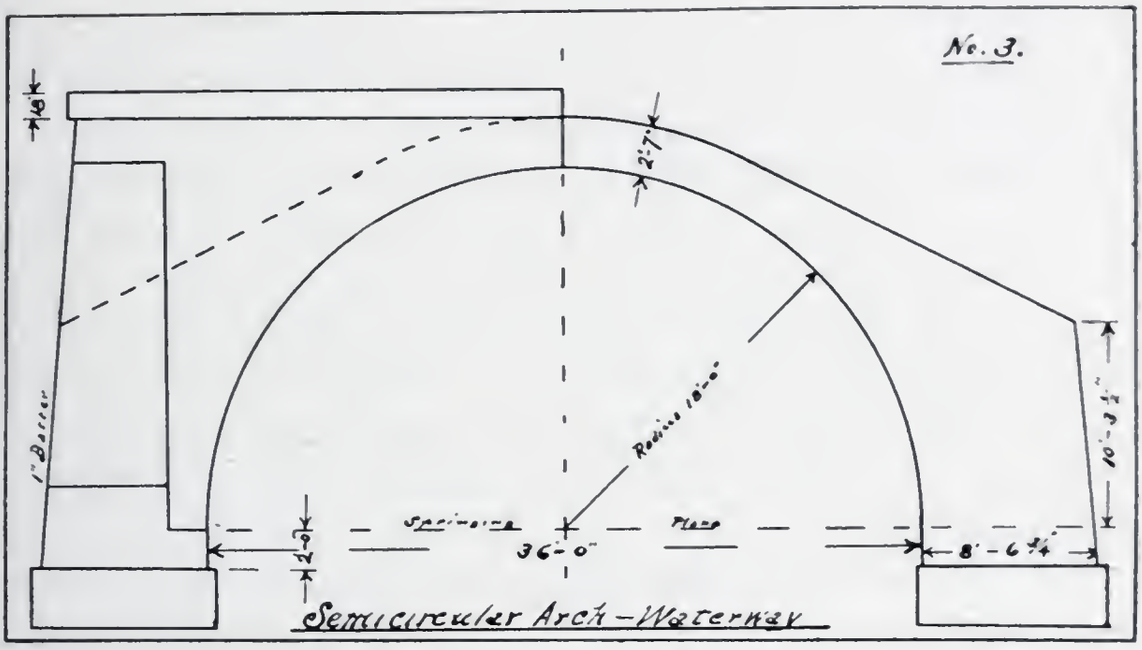
No. 1 Miller Arch, 1,493 cubic yards, at. $4.85
No. 2 Leek Run Arch, 2,223 cubic yards, at. . . . 5.09
No. 3 Hall Arch, 2,521 cubic yards, at. 4.95
No. 4 Arch at Isabella Furnaces, 179½ cubic yds, at. 5.00

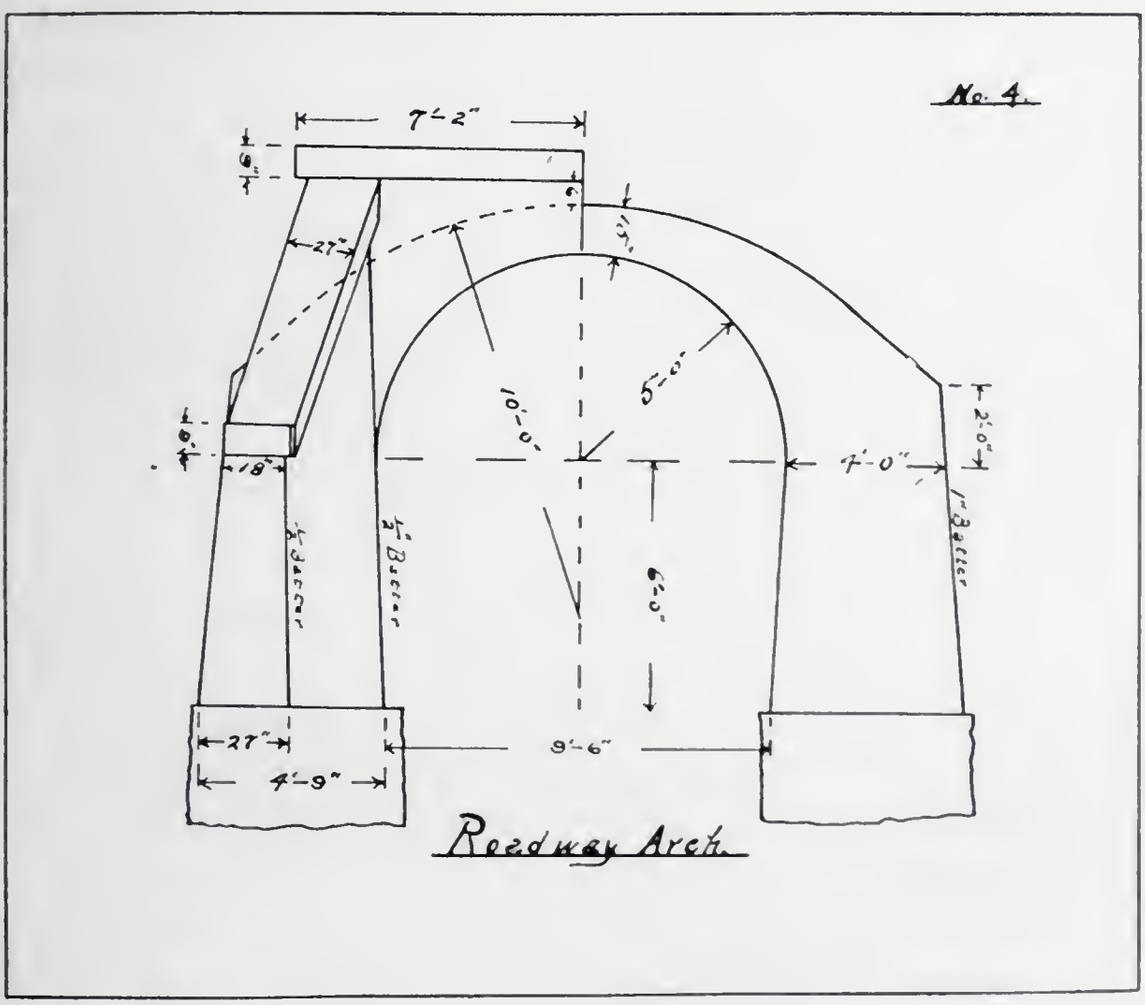
These prices include excavations for foundations, and all incidental expenses, except filling.

The first three of these arches are remarkable for the fact that one part cement, two parts sand and ten parts gravel were used, except within 15 inches of exposed surfaces and in arch ring, where one-half part of cement was added. The sand in the gravel increased the proportion of sand in the mortar somewhat. The other extreme in modern practice that has come to my notice, is the concrete masonry on the Wabash Railroad, where the proportion of 1-3-5 (broken stone) is used. The difference lies


16'-11"
No. 1.
18'-3"
7'-7"
Springing Plane
6'-11"
16'-6"
12'-7"
Semicircular Arch - Road & Waterway


No. 2.
Springing
Plane
6'-11"
7'-5"
16'-0" Span.
For Waterway.
Semicircular Concrete Arch.
36'-0" Span.
For Roadway.


No. 3.
2'-7"
Radius 18'-0"
1'-0"
Spring Line
Floor
36'-0"
8'-6 3/4"
10'-3 1/2"
2'-0"
1" Batter
Semicircular Arch - Waterway


No. 4.
7'-2"
6"
27"
2'-1"
5'-0"
10'-0"
1'-6"
18"
4'-0"
2'-0"
1" Batter
1/2" Batter
1/2" Batter
6'-0"
27"
4'-9"
9'-6"
Roadway Arch.

principally in the mortar. On the Union Railroad the mortar was strong and the concrete lean, (that is, insufficient mortar to fill the voids in the gravel). On the Wabash Road, the mortar was weak and the concrete very rich, (that is, an excess of mortar). All the records of tests of concrete within my reach, show the lean concrete, (within limits) to be the strongest. This seems perfectly reasonable, for if the pieces of the aggregate are permitted to come into close contact, the strength of the concrete under compression will approach the strength of the aggregate, while if the aggregate is bedded in a great amount of mortar, the strength of the concrete will be no greater than that of the mortar. Concrete should be stronger than the mortar of which it is made. These arches are remarkable also for the fact that gravel alone was the aggregate used. It is desirable to use gravel on account of its cheapness, and because it is hard and strong.

I have said that concrete masonry is built of the same dimensions as the best stonework, but to do this, the concrete must be of the best quality. This raises the question: "What is the best quality, and how can it be obtained?" The examples I have given show the latitude used in practice for proportioning the ingredients. With a given matrix and a given aggregate, the very important point arises to get a bond between them as strong as the aggregate; this done, it can be safely said that the concrete is "as strong as possible." To obtain this condition, our practice has taught us the following rules:

1st. Sand and gravel washed perfectly clean.

2nd. Thorough mixing.

3rd. Concrete to be just damp.

4th. Laid in thin layers and tamped exceedingly hard with a heavy ram.

Perhaps some will take exception to "dry" concrete, but our work has shown it to be the best. In "wet" concrete all the water present in excess of that needed for perfect setting, is an inert substance, which, when it evaporates, leaves a void in the masonry. Thus, concrete mixed wet is necessarily full of voids, and to that extent weakened. Another important point gained by having the concrete dry and well tamped is that it is heavier. Two sample bricks, one very dry and the other quite wet, showed the dry con-

crete to be about 5 per cent. heavier; its actual weight was 154 pounds per cubic feet.

I do not care to open a discussion as to how concrete should be mixed, for no two engineers, perhaps, will agree as to the exact method, but simply state the results of our experiments and practice.

The subject of the testing of concrete to ascertain whether it is coming up to the requirements, is a very interesting subject and extremely important. A small test piece is of little value, for it is not an average sample. A sufficiently large piece is heavy to handle and difficult to break, as a machine is seldom available. In testing concrete the writer has employed the principle already stated viz: when the mortar and the bond between the mortar and the aggregate are of sufficient strength, the brick, marked around with a cutter, will break in a rather smooth plane, and every particle of the aggregate in this plane will break in two. The quality of the concrete is expressed by the percentage of the aggregate broken.

We can issue any amount of specifications, but it is the result produced by them that we are really interested in, for that is the aim of the specifications.

The President — Gentlemen, I am especially glad to have had this short but concise little paper given us. In this connection, I would like to remind you of the paper that was read before this society some time ago, on the concrete track over in Allegheny. If anyone will look back to that paper, they will see the comparative cost of mixing concrete by hand and by machine, and a great deal of other valuable information regarding concrete work on that job. That paper would be in place to-night. Our time is getting short, and we have with us to-night Mr. Kirk, son of Mr. Kirk who has been so long a member of our society, and who represents a manufacturer of a special concrete mixer. The subject is a very important one, and, if Mr. Kirk can give us a few points on the general subject, without making it a question of advertising, we will be very glad to hear him.

Mr. Kirk — With concrete there is a great difference in the thoroughness in which you incorporate the different ingredients.

I have seen, in windy weather, the dry cement blow out. Now with machines it is possible to give a batch forty turns, as against four or five by hand. I have tried to get some figures as to mixing concrete by hand, but those who have them are ashamed to give them. With machines it is possible to make it at 250 to 300 feet in ten hours, at a cost of eighteen, twenty-three, or twenty-five cents. I will try to steer clear of advertising, but, if it is interesting to any, I will give you a little catechism that we have compiled on this subject.

THE PRESIDENT — Our time is passing rapidly, and yet the subject is so important and so interesting that I am sure we will not begrudge a few minutes longer for general discussion. I am sure a good many here will be glad to ask questions, and some who can, we will ask to answer them. All that I ask is that you make them to the point. The topic is now open for discussion.

A MEMBER — The subject of making concrete waterproof is probably quite feasible. Two conditions generally arise. You can put a glass finish on the outside, but sometimes you have to make the concrete itself waterproof. For instance, in lining a tunnel, where you have to put concrete ahead of you, and have all the voids absolutely filled. I would like to hear if anyone has ever put a foreign substance, something that would fill up all the voids and make the concrete absolutely water tight. I remember reading in some book of introducing a material like precipitate of aluminum or matter like you get if you precipitate aluminum, and I have seen hard soap tried, and I know it works all right in mortar. Soap makes it water tight. I wonder what the opinion is of men who have had that work to do? You could use other matters besides cement to make it water tight. I built a floor in Philadelphia two years ago, and used asphalt in the sand. There were 32 per cent. voids. To that I added ground carbonate of lime, passed through a 200 mesh. I got the voids down to 10 per cent., and to that I added 12 per cent. of asphalt, and had a very tight floor, but it was a soft floor, and I had to put other material over it to protect it. In concrete work, I think something like that could be done, too.

A MEMBER — Quite recently I had a conversation with a friend of mine who has had some experience along that line. I

raised the question as to how concrete could be made impervious to water, and he says he uses water from scrap iron, placing in it rusty water cups, scrap iron, etc., until it becomes rusty, and uses that water in mixing his cement. He says he accomplishes his end in that way. It would be worth while to experiment on this line.

MR. ROBERTS — Mr. Smith raised a very interesting question about the amount of water to use in concrete. I have changed my views to a certain extent in regard to that. I believe that if it is rammed well, it is all right, but the trouble is to get it rammed down properly. Those voids are in the dry cement, and water tends to pack things down. It is very important to have it well rammed. A great many gangs of men will work faithfully while you look at them, and not do much if you don't watch them.

THE PRESIDENT — What is your plan, Mr. Cummings?

MR. CUMMINGS — Make it wet. I would like to mention a plan some contractors use by which they secure the best results. They use ground limestone instead of sand which makes a very smooth, glassy, surface, impenetrable to water.

MR. WHITED — I think that, with waterproof concrete, a great deal depends upon the thoroughness with which it is mixed. If grains of sand run through, it will leak. I do not think that it is good for sidewalk purposes. It makes it too slippery. This concrete steel subject is a burning subject, and I know a good many places where it could be used to advantage. I found it difficult to get reliable literature on the subject. Advertising literature may be all right, but it takes away its value. I looked into some of the foreign periodicals, and find that it has been used in France, Austria, Germany, but probably more in Austria than in any other country. In France it was used first in making jardinieres, water pipes, and such things as that. They made wire in the spiral form, and filled the meshes enough to cover it with concrete so as to make it water tight. That has been used so much in France that surely they have solved the problem of making it water tight. It is an interesting problem whether a pipe or metal imbedded in concrete will be corroded. The only light I have been able to find so far in the discussion before the German Society of Engineers, and that showed conclusively that it had been used very lately in

Germany, and there had been very little difficulty. The work must be well done. That is the important thing. It must be well made, well rammed, and well mixed.

MR. BROWN — Regarding the subject of mixing concrete with machines, there are a number of machines of different types that are used. I have used three myself. As far as concrete being mixed is concerned, I think they are mixing it about as well as it can be mixed in any machine. There is one gravity machine that I had in New York rapid transit work that worked better than anything I have ever seen tried. It was designed by Gen. Haines of the United States Army. In the gravity machine, the material was dropped on to one door which opened and dropped on to another and down into the tunnel. It was a very nice place to use the machine; the material just going down in the direction I wanted it to go. The cost was about eight cents per yard. A cubical box mixer takes five or six men to run it, that is getting the sand and material up to it, which cost about eighteen cents per yard. I am using one now that is made by ————————, and that concrete is costing about 12 to 14 cents to mix it under favorable conditions, and load it into the car below. Those three, I think, are the best or the most thorough mixers. That gravity machine of Gen. Haines' is the only one that mixes thoroughly so that there are no gravel streaks in it. There are other gravity machines which will do on some classes of work where the material does not have to go through very fast, say up to 75 to 100 yards per day. Gen. Haines' machine on bridge No. 3 made 800 yards in 10 hours. The Carlin 600 yards in 18 hours, and the other machine 200 yards in 10 hours.

MR. ROBERTS — Just one point in regard to the possibility of iron rusting in concrete. I believe there is no possibility of any oxidation of iron or steel in concrete. I had a mason's hammer which was found four feet under water, and about four inches away from the face of the masonry. It was so bright on the end of the hammer that it still had the glistening surface on it. There is something about the action of concrete that absorbs the free oxygen in the air.

A MEMBER—I would like to state that in tearing down

a postoffice building in Chicago, a number of beams extended into the wall, and they were perfectly bright. The ends of the beams were entirely bright, showing that no oxidation had taken place.

THE PRESIDENT — I would say that there has been quite a good deal in the papers lately about some buildings taken down in New York. Out about 46th St., some buildings were taken down which were of steel construction, and architects have been examining the material that came out of them with a great deal of interest, and I hear varying reports. I heard one engineer say that all were so rusty that it is only a question of time until the high buildings of New York fall down like a bunch of cards. Others say they were not injured in the least; so you must pay your money and take your choice. But it seems that, if it is covered so that the moisture does not get at it, corrosion does not take place. If water is kept away from it, very little damage will ensue. I have here a little curiosity. Just a piece of concrete which was in steady use for 23 years, and which seems to be in good condition.

MR. BROWN—There is an article in the last number of the Deutsch Engineer on that question. It gives an account of where they took up a sewer that was put in in 1870, and in which concrete beams were imbedded. The sewage water had a chance to work on it, too. The iron was coated with a small amount of calcine of iron, but the section had not decreased a particle. There was this thin scum over the whole of the beam, covering it with this white iron salt, and the beam was just as good as when put in.

A MEMBER — The Institute of Technology made some tests on steel imbedded in cement for the purpose of finding out if it would rust. The report was made in the last December number of the Technology Report. As I remember it, all sorts of conditions prevailed. Some had rusted and some was just as bright as when put in. One of the essentials was that the steel had to be clean and to be coated with cement to exclude the air. If the steel went in rusty the rusting would continue. Experiments were conducted on a small scale. If anyone is interested he will find this in the Technology Report.

PROF. KINTNER — I would like to ask about the expansion of the concrete and steel in these re-inforced beams, whether they expand at the same rate or not.

THE PRESIDENT — I understand that the expansion of concrete and steel are very nearly the same, although I cannot say definitely.

On motion the Society adjourned at 11 o'clock.

CHAS. W. RIDINGER,
Secretary.

STRUCTURAL SECTION.

Assembly Room Engineers' Society of Western Pennsylvania, 410 Penn Avenue, Pittsburg, Pa., March 10, 1903. Structural section called to order by the Temporary Chairman, Mr. J. K. Lyons, at 8:30 p. m., 21 members present.

Minutes of the previous meeting read and approved. Report of Committee on By-Laws presented. Moved and seconded that section 1 be adopted; carried. Moved and seconded that Art. 2 be adopted, changing researches to research; carried. Moved and seconded that Art. 3 be adopted, omitting in the second sentence "of the Engineers' Society of Western Pennsylvania." Moved to amend by making election to consist of application to Secretary of the society. Amendment carried. Motion carried.

Moved and seconded that Art. 4 be adopted; carried. Moved and seconded to amend Art. 5 by adding a committee on shop methods and committee on concrete-steel construction; carried. Moved and seconded to amend Sec. 1 by inserting the words "at and seconded that Art. 7 be adopted; carried. Moved least" between "consist of" and two members; carried. Moved and seconded that Art. 5 be adopted as amended; carried.

Moved and seconded that Art. 6 be adopted; carried. Moved and seconded that the by-laws as amended be adopted as a whole, subject to approval by Board of Direction; carried.

Report of Committee on Permanent Organization presented as follows:

J. K. LYONS, *Chairman,*
FRANS ENGSTROM, *Vice Chairman.*
WILLIS WHITED, *Secretary,*
F. A. MCDONALD,
MORRIS KNOWLES,
Directors.

An informal discussion was had of the subject assigned for the evening: Highway Bridge Floors, participated in by various members.

Subject assigned for discussion for the next meeting, March 24, 1903: Pneumatic Caissons. On motion section adjourned.

WILLIS WHITED.

By-laws, as amended. By-laws of the Structural Section of the Engineers' Society of Western Pennsylvania:

ART. 1. The name of the organization shall be "The Structural Section of the Engineers' Society of Western Pennsylvania."

ART. 2. The object shall be the consideration of papers and subjects connected with the constructional engineering and the encouragement of research and investigation in the same, in so far as it applies to structures of timber, masonry, iron, steel, etc.

ART. 3. Members of the Section must be members of the Engineers' Society of Western Pennsylvania. Members may become members of the Structural Section by application to the Secretary of the Society.

ART. 4. The officers of the Section shall be Chairman, Vice Chairman, Secretary and two Directors. They shall constitute the Board of Direction and shall hold office for one year.

The officers shall be elected at the annual meeting and shall require for election a majority of the votes cast.

The Board of Direction shall, in addition to attending to the executive business of the Section, arrange programs for the regular meetings.

ART. 5. The Section shall have the following standing committees:

(a)—Committee on Timber Construction.

(b)—Committee on Masonry Construction.

(c)—Committee on Rolling Mill Practice.

(d)—Committee on Railroad Bridge Construction.

(e)—Committee on Highway and Trolley Bridge Construction.

(f)—Committee on Mill Building Construction.

(g)—Committee on Office Building Construction.

(h)—Committee on Shop Methods.

(i)—Committee on Concrete-Steel Construction.

These committees shall consist of at least two members appointed by the Chairman.

The duty of these committees shall be to report to the Section at each meeting on current matters relating to work or designs in their respective fields.

ART. 7. Meetings.

a—Regular meetings for the reading of papers and discussion of scientific and technical subjects shall be held on the fourth Tuesday of each month, except during the months of June, July and August.

b—The annual meeting shall be held on the same day as the regular meeting for January.

c—Special meetings may be called by the Chairman or at the written request of five members.

Notices of special meetings shall be mailed to each member at least two days in advance of said meeting.

Notices of special meetings shall contain a statement of the object for which the meeting is called, and no subject not stated in the notice shall be decided at any special meeting.

d—Ten members shall constitute a quorum at all meetings.

e—The following order of business shall be observed at the annual meeting:

1. Reading of minutes of last annual meeting.
2. Report of Secretary.
3. Annual report of the Board of Direction.
4. Reports of special committees.
5. Address of retiring Chairman.
6. Election and announcement of election of officers.
7. Adjournment.

f—The following shall be the order of business at the regular meetings:

1. Reading of minutes of last regular meeting and of subsequent special meetings.
2. Report of the Board of Direction.
3. Unfinished business.
4. Reports of committees.
5. New business.
6. Miscellaneous announcements, papers, items, notes or communications.
7. Adjournment.

g—In all questions arising at any meeting involving parliamentary rules, Cushing's Manual shall be accepted as authority.

ART. 7. Amendments to the by-laws must be proposed in writing by at least three members at a regular meeting and adopted by a two-thirds vote at a subsequent regular meeting, provided notice of such amendment be sent to each member with notice of meeting.

CHEMICAL SECTION.

The regular monthly meeting of the Section was held on Thursday evening, March 19th, in the rooms of the Society, the Chairman, Mr. H. W. Craver, presiding.

The minutes of the last regular meeting were read and approved. Mr. Camp, on behalf of the Board of Direction of the Engineers' Society, extended to the newly formed Pittsburgh Section of the American Chemical Society the privilege of the rooms of the Society for joint meetings with the Chemical Section of the Engineers' Society, the invitation being gratefully accepted.

The paper of the evening, "The Analysis of Bronzes and Bearing Metals," by Messrs. H. E. Walters and O. I. Affelder, was then read by Mr. Walters. The subject was discussed by the members present.

Upon motion, the Section adjourned.

CHAS. H. RICH, *Secretary.*

THE ANALYSIS OF BRONZES AND BEARING METALS.

BY H. E. WALTERS AND O. I. AFFELDER.

In the laboratory with which the writers are connected, many bronzes and bearing metals are analyzed, and it was thought that the methods which are used might prove of interest to the members of this Section.

While the scheme contains much that is old, we wish to call particular attention to the volumetric method for determining lead, as the results obtained by it are as reliable as those obtained by the sulphate method.

The analysis of bronzes is carried out as follows:

Weigh one gram of the sample (0.5 gram if the lead is over 15 per cent.) into a No. 2 beaker, cover with a watch glass, add 10 cc nitric acid (1.42 Sp. gr.) and warm until all is dissolved. When in solution add 40 cc hot water and boil five (5) minutes, filter, wash with two (2) per cent. nitric acid, burn and weigh as

Sn. O2. To the filtrate add 25 cc strong ammonia and heat to boiling, then add about five (5) grams ammonium persulphate and boil from five to ten minutes. Make acid with sulphuric acid, filter and wash with hot water. The lead will remain on the filter as lead peroxide. Transfer the precipitate and filter to the beaker in which precipitation was made, add water and stir well to disintegrate the filter paper. Dilute to 600 cc-700 cc with cold water, add about three grams potassium iodide and some starch solution. When all the iodide is dissolved add 10cc hydrochloric acid (one acid—one water), stir well and titrate with one-twentieth normal sodium thiosulphate until the solution changes from the dirty and dark yellow color to a bright lemon yellow; or, an excess of sodium thiosulphate may be added and the excess titrated with one-twentieth normal iodine solution until the color changes from the bright yellow of the lead iodide present to the dirty and dark yellow. The number of cc of sodium thiosulphate used multiplied by .5175 will give the percentage of lead.

Where speed is not desirable the lead may be determined by adding sulphuric acid to the filtrate from the oxiade of tin or the lead and copper may be deposited with the electric current. Dilute the filtrate from the lead peroxide to 500 cc, heat to boiling and add 50 cc of a 20 per cent. sodium thiosulphate solution, boil five minutes, filter, wash with hot water, burn, and weigh as Cu O.

Copper may also be determinel by the following method:

Dissolve 0.5 gram of the sample in 10 cc nitric acid (1.42 Sp. gr.). When in solution dilute with cold water and add sodium carbonate until the solution is alkaline, make acid with acetic acid and add about three (3) grams potassium iodide and some starch solution. Titrate with a sodium thiosulphate solution which has been standardized with pure copper. Oxidize the filtrate from the copper sulphide with nitric acid and potassium chlorate and evaporate until the volume is about 300 cc. Make a basic acetate separation and determine iron or aluminum by the well known methods. Make the filtrate from the iron or aluminum strongly alkaline with ammonia, heat to boiling and add ammonium persulphate, boil five minutes, filter and wash with hot water, burn and weigh as Mn^3O4.

To the filtrate from the manganese add ammonium phosphate

in excess, heat to boiling and add hydrochloric acid until there is but a slight excess of ammonia, boil five minutes, filter and wash with hot water. The precipitate may be dried and weighed as Zn NH_4 PO_4, or it may be filtered on a Gooch crucible and ignited to Zn_2 P_2 O_7.

It may also be titrated with standard acid and alkali (Footnote Walker J. A. C. S. 23-468).

Any nickel which may be present will be found in the filtrate from the zinc and may be precipitated as sulphide and ignited to Ni O. If manganese is present in small quantities it may be determined in separate portion by the following method:

Weigh 0.2 gram of the sample into a suitable test tube, add 10 cc nitric acid (1.20 Sp gr.) and warm until the sample is dissolved and all nitrous fumes are driven off. Add 15 cc silver nitrate solution (1.33 grams of the salt to one liter of water) and about 0.5 gram ammonium persulphate, warm until the manganese is oxidized to permanganic acid, cool, transfer to a beaker and dilute to 100 cc, titrate with standard sodium arsenite or hydrogen peroxide until the disappearance of the pink color.

To determine phosphorus dissolve one gram of the sample in 5 cc fuming nitric acid, evaporate to expel most of the free acid, add 10 cc conc. hydrocholoric acid and evaporate to dryness. Dissolve the residue in hydrochloric acid and water, heat to boiling and precipitate lead, tin and copper with metallic zinc, filter and wash with hot water. To the filtrate add some iron solution free from phosphous and 10 cc nitric acid (1.42 Sp gr.), boil a few minutes and then precipitate with ammonia and filter to separate most of the zinc, dissolve the precipitate in hot nitric acid (1.20 Sp. gr.) and precipitate the phosphorus with molybdate solution. The yellow precipitate may be weighed or titrated.

BEARING METALS.

If the sample is high in tin and low in lead proceed as outlined for bronzes, but if the sample is high in lead and contains antimony, proceed as suggested by Mr. George Hopkins, chemist to the Carrie Furnaces of the Homestead Steel Works, he having found that the addition of an excess of pure tin will insure the complete separation of the antimony with the oxide of tin.

Weigh 0.5 gram of the sample and 0.25 gram of pure tin into a tall No. 2 beaker, cover with a watch glass, add 20 cc nitric acid (1.33 Sp. gr.) and boil down to pastiness, add 40 cc hot water and boil a few minutes, filter and wash with two (2) per cent. nitric acid, burn and weigh as $SNO_2 + Sb_2O_4$. The filtrate is made strongly alkaline with caustic potash and the lead oxidized by adding about 10 grams ammonium persulphate. The rest of the analysis is carried out as outlined for bronzes.

To determine antimony (Foot note J. A. C. S. 17-872) weigh (1) gram of the sample and (1) gram potassium iodide into a No. beaker, add 80 cc hydrochloric acid (1.10 Sp. gr.) and boil gently for one hour, filter on a weighed paper or Gooch crucible and wash with dilute hydrochloric acid and then with hot water until free from chloride. Wash once with alcohol, dry for one hour at 100° C. and weigh. The increase in weight is metallic antimony. Calculate this to Sb_2O_4 and subtract from the weight of the mixed oxides, calculate the tin from the weight of stannic oxide found and subtract the tin which was added.

Arsenic is determined on a separate portion by any of the well known distillation methods.

Bismuth, if present, would be found with the copper sulphide, and can be determined by dissolving the sulphides in nitric acid and precipitating the bismuth with ammonia.

REMARKS.

It will be noted that the filtrate from the tin in bronzes is made alkaline with ammonia, while for bearing metals caustic potash is used. If caustic potash be used for bronzes the copper would be precipitated and the lead would not be completely oxidized, while if the filtrate of a high lead bearing metal is made alkaline with ammonia the lead hydroxide precipitate would be of such large volume that complete oxidation would not take place.

In filtering the lead peroxide it is necessary to add some paper pulp to the filter, otherwise some of the precipitate will run through.

Should manganese be present the lead will have to be determined by the sulphate method, as the oxide of manganese would

be precipitated with the lead peroxide and would not dissolve in the sulphuric acid added.

While we have not made many experiments, we feel safe in saying that the manganese could be separated direct from the copper sulphide filtrate if most of the sulphuric acid is neutralized and the solution oxidized with ammonium persulphate.

In determining lead by the sulphate method or by the electrolytic method a large amount of time is consumed in evaporating to sulphuric fumes or in the long passage of the electric current, while by the titration method, if lead only is wanted, it may be determined without separating the tin and the time required will be about thirty minutes.

If the copper is determined by the volumetric method, tin, lead and copper results will be obtained in about one hour.

The following lead results were obtained on the same samples by the sulphate and volumetric methods:

Sample.	Sulphate Method.	Volumetric Method.
Bronze No. 4	2.60	2.61
Bronze No. 2	4.68	4.71
Bronze H	5.05	4.97
Bronze No. 1	5.39	5.33
Bronze A	5.67	5.62
Bronze B	7.47	7.51
Bronze M	9.77	9.73
Bronze S	13.72	13.62
Bronze A.P.	26.68	26.55
Babbit C	3.29	3.41
Babbit D.S.	65.85	65.93
Babbit L	80.80	80.73
Babbit D	89.63	89.50

Laboratory,
United Engineering & Foundry Company,
Lincoln Foundry Company Dept., Pittsburgh, Pa.

STRUCTURAL SECTION.

A regular meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held at the rooms of the Society, at 410 Penn Ave., Pittsburg, Pa., March 24, 1903, 22 members and visitors being present. Meeting called to order by the Chairman, Mr. J. K. Lyons, at 8:30 p. m. Minutes of the previous meeting were read and corrected.

C. B. Albree, President of the society, reported from the Board of Direction that the petition for the formation of his section, accompanied by the by-laws as adopted by the section, had been accepted by the Board of Direction.

Subject for discussion: "Pneumatic Caissons." Remarks were made on this subject by Marshall Brown, Orville Benson and others.

Subject selected for the next regular meeting, "Mill Buildings."

On motion Section adjourned.

WILLIS WHITED, *Secretary.*

MECHANICAL STOKERS.

Presented Before Mechanical Section Engineers' Society of Western Pennsylvania.

BY EDWIN FITTS.

In taking up the subject of mechanical stoking, I wish first to go over in a general way what takes place in a furnace, or in other words, what the burning of fuel is. Fuel in this case can be taken as meaning coal and for our present purpose it will only be necessary to consider the three principal ingredients of coal. These are fixed carbon, hydrocarbons and the ash. Hydrocarbon is a term used to designate a large number of substances formed by combinations of hydrogen and carbon in different proportions. In burning, these substances are first driven off by heat in the form of a gas, and there then remains the solid portion of the fuel which is made up of coke, or fixed carbon, and non-combustible earthy and mineral matters.

The percentage of fixed carbon is used as a means of classification. Coal having more than 92.3 per cent. of fixed carbon is anthracite, that having between 87.5 and 92.3 per cent. is semi-anthracite form, 75 to 87.5 per cent. is designated as semi-bituminous and all coals having less than 75 per cent. of fixed carbon are bituminous.

Combusion or burning is a chemical phenomena. Rankine gives the definition of combustible as a substance "capable of combining rapidly with oxygen so as to form heat rapidly."

For the following theory of combustion I am indebted to Kent. Of the solid portion of the coal he says: "Fixed or free carbon is left in the form of coke after the volatile ingredients have been distilled away. These ingredients burn either wholly in the solid state C to CO_2 or part in the solid state and part in the gaseous state. $CO+O=CO_2$, the latter part being first dissolved by previously formed carbonic acid by the reaction $CO+O=CO$. Carbonic oxide, CO, is produced when the supply of air to the fire is insufficient."

Of the volatile matter he says: "Hydrocarbons all must pass into the gaseous state before being burned."

"If mixed on their first issuing from amongst the burning carbon with a large quantity of hot air, these inflammable gases are completely burned with a transparent blue flame, producing carbonic acid and steam. When mixed with cold air they are apt to be chilled and pass off unburned. When raised to a red heat, or thereabouts, before being mixed with a sufficient quantity of air for perfect combustion, they disengage carbon in fine powder and pass to the condition partly of marsh gas and party of free hydrogen; and the higher the temperature, the greater is the proportion of carbon thus disengaged."

"If the disengaged carbon is cooled below the temperature of ignition before coming in contact with oxygen, it constitutes, while floating in the gas, smoke, and when deposited on solid bodies, soot."

"But if the disengaged carbon is maintained at the temperature of ignition, and supplied with oxygen sufficient for its combustion it burns while floating in the inflammable gas and forms red, yellow or white flame. The flame from fuel is the larger the more slowly its combustion is effected. The flame itself is apt to be chilled by radiation, as into the heating surface of a steam boiler, so that the combustion is not completed, and a part of the gas and smoke pass off unburned."

As to the oxygen and hydrogen we are not much concerned, the fuel in the form of water, H_2O, or in proportions to form water. "Such quantities of oxygen and hyrogen are to left out of account in determining the heat generated by combustion. If the quantity of water actually or virtually present in each pound of fuel is so great as to make its latent heat of evaporation worth considering, that heat is to be deducted from the total heat of combustion of the fuel."

For the heat of combustion of carbon Rankine gives us the following figures:

One pound of carbon burned to CO requires 1 1-3 lbs. of oxygen or 6 lbs. of air, and gives off 4400 B. T. U. with an evaporative power of 4.55 lbs. of water from and at 212° F.

One pound of carbon burned completely to CO_2 requires 2 2-3 lbs. of oxygen or 12 lbs. of air and gives off 14500 B. T. U. with an evaporative power of 15.

Heat losses due to imperfect combustion of the carbon of the coke may occur in the following manner and quantities. The burning of solid carbon is always complete at first, that is, 1 lb. of carbon unites with 2 2-3 lbs. of oxygen and makes 3 2-3 lbs. of carbonic acid gas. This terminates the process if the layer of carbon is not too thick and the supply of oxygen is ample. In the case of a very deep fire or one not having sufficient supply of oxygen a portion of the carbon is volatilized by the carbonic acid. Each 3 2-3 lbs. of CO_2 formed are capable of dissolving one pound of carbon and forming 4 2-3 lbs. of carbon mon-oxide. In this case the heat produced, instead of being that due to the complete combustion of one pound of carbon 14500 B. T. U., becomes that due to the combining of two pounds of carbon into CO, or 2x4400=8800 B. T. U. and we have a loss of 5700 B. T. U. If no more oxygen is supplied and the gases pass off in this condition the heat loss is very great. But if we give this CO that is formed a further supply of oxygen and maintain the gas at a high temperature each 4 2-3 lbs. of carbonic oxide containing two pounds of carbon will unite with 2 2-3 lbs. of oxygen and form 7 1-3 lbs. of carbonic acid gas. The heat due to this combination will be 20200 B. T. U., to which we must add that due to the burning of 2 lbs. of C to CO or 8800 and we have 29000 B. T. U., the same as that due to the direct burning of two pounds of carbon CO_2.

From what we now have before us it is evident that the object sought in a boiler furnace is the bringing about of the chemical reaction $C+2O=CO_2$ either direct or in the manner I have explained. In my opinion there are two things necessary to accomplish this. One is to admit hot air above the fire and the other is to cover the entire fire surface with a fire brick roof, in order that the gases may be maintained at a combining temperature until all reactions are complete.

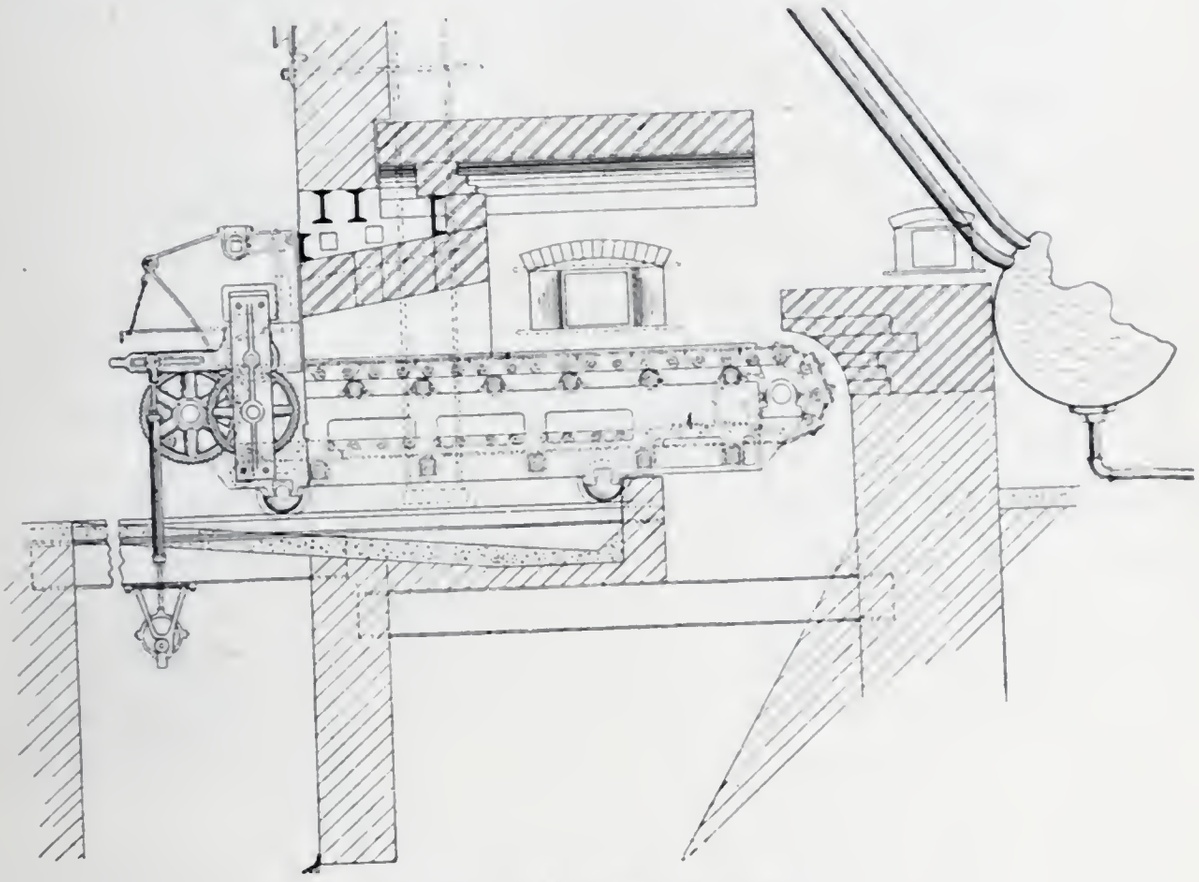
We are now ready to take up the different forms of boiler furnaces and will first turn to the oldest or hand-fired type.

In the ordinary hand-fired furnace all the oxygen for com-

bustion of both the fixed carbon of the coke and the hydrocarbons is brought up through the grates and the bed of burning fuel. The fresh fuel is added at all points of the grate area by means of a shovel in the hands of the human stoker. In the process of firing, the fireman first pulls open the fire door, and thus admits a large volume of cold air, which chills the products of combustion that have already been formed. This amount of air depends upon the length of time the door is left open, but if the door is open a short time, only a small amount of fuel can be added and length of time between openings must be made short. The loss due to this will be about the same under all conditions of firing. When this fresh charge of fuel is added the first thing that takes place is the distilling of the volatile matter. The process of burning of these gaseous products I have already described, and you can very readily see that here we have none of the conditions mentioned as being necessary for complete combustion. The oxygen has all been brought CO or CO_2 in passing through the bed of coke below. What CO_2 has been formed will be broken to CO by the C of these gases and we will have no CO_2 passing out of the stack. Even if there is a great excess of air admitted through the fire, so that we have free oxygen, we can scarcely expect to burn these carbonaceous gases, as they chill rapidly by radiation into the heating surfaces of the boiler. Many people think that heating surfaces should be brought as near the fuel bed as possible, but this is one of the greatest errors that can be made. They should be kept away in order to give the gases time to mingle and burn. As to relations between smoke and ecenomy in hand firing, we may have a smoky fire and fairly good economy, and we may have a clear stack and very poor economy. The weight of carbon sent off as smoke is very small, and if we have no CO and no free oxygen the loss will not be excessive, but if we have a high percentage of CO, which is an invisible gas, the loss will be very great, even with no visible free carbon. With hand firing neither one of these conditions is often obtained, but there is a smoky stack and high CO.

It is very evident that the greatest loss in hand firing occurs just after the charging of fresh fuel in large quantities and that it is due to the fact that there cannot be a sufficient supply of

oxygen brought up through the bed of fuel to supply the excessive demand at such times.



"Green" Traveling Link Grate.

The smaller each charge of fuel is and the less time elapsing between charges, the less the variations in the quantity of air demanded. This brings us to mechanical stoking and an almost continuous supply of fresh fuel, requiring no variaition in the quantity of air supplied, and added to this, there is no opening of fire doors, with the accompanying loss.

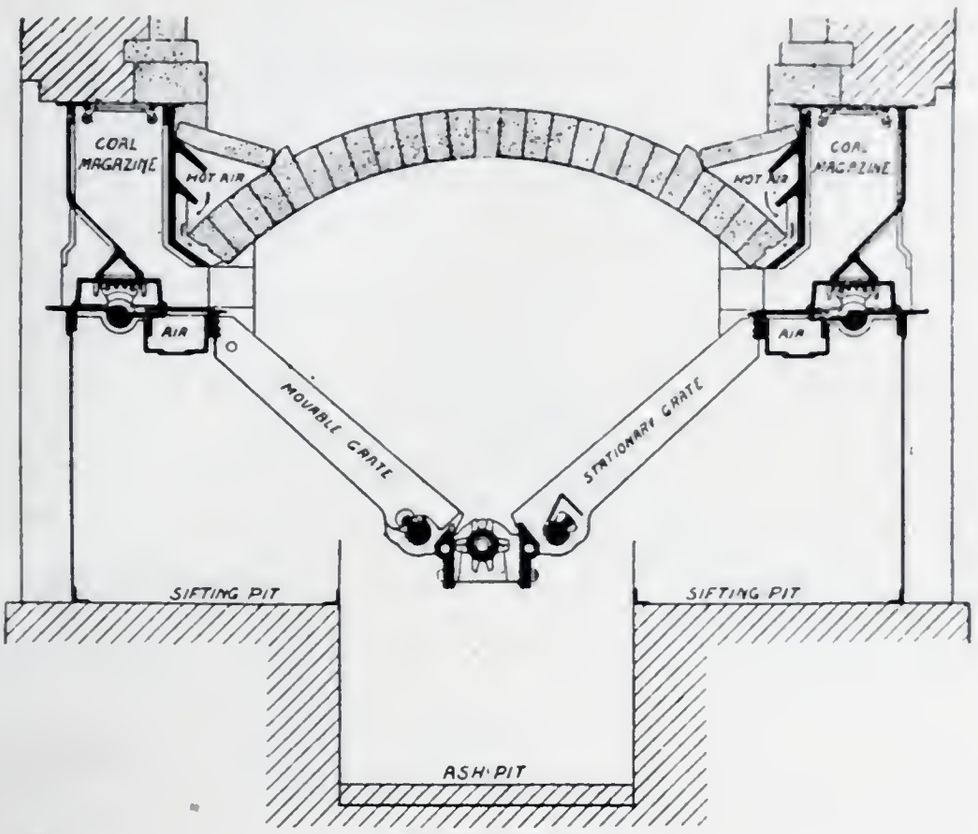
As to the history of mechanical stoking, we are not much concerned, but a few words will not be out of place. The first to use the idea of progressive burning of coal was James Watt. He distilled the coal on a dead plate at the mouth of the furnace and then pushed the coke back over the grate area by hand. In this way a fairly good combustion can be obtained, but the labor is very excessive. Many variations of this scheme were brought out from time to time, but the first mechanical stoker was patented in 1841 by John Juckes, an English inventor. This was of the tread mill type and is in extensive use to-day, having been changed in detail of construction, and is now known as the chain grate stoker. There are a number of different makes of chain

grates on the American market, and for fear of being considered biassed toward one maker I will describe them as a class.

The term, treadmill type, comes from the fact that the grates are built like the apron of a treadmill and pass over sprockets at the front and rear of the furnace. The grate surface is horizontal and the grates are moved from front to rear, on the top, by power applied to the front sprocket shaft. Immediately at the front of this grate surface is a hopper extending the entire width and having at its back side a plate which can be raised and lowered to govern the thickness of the bed of fuel. Immediately back of this hopper and extending the entire width of the grates is a firebrick arch. The proportion of the entire grate surface covered by this arch varies in the different makes of chain grates. In the operation the hopper is filled with coal, which is carried back by the movement of the grates and begins to burn as it comes underneath the igniting arch. The bed of fuel continues to move back until it reaches the rear end of the grates, when, what is left is dumped over into the ash pit below. The fuel bed is not disturbed in any way during the period of burning.

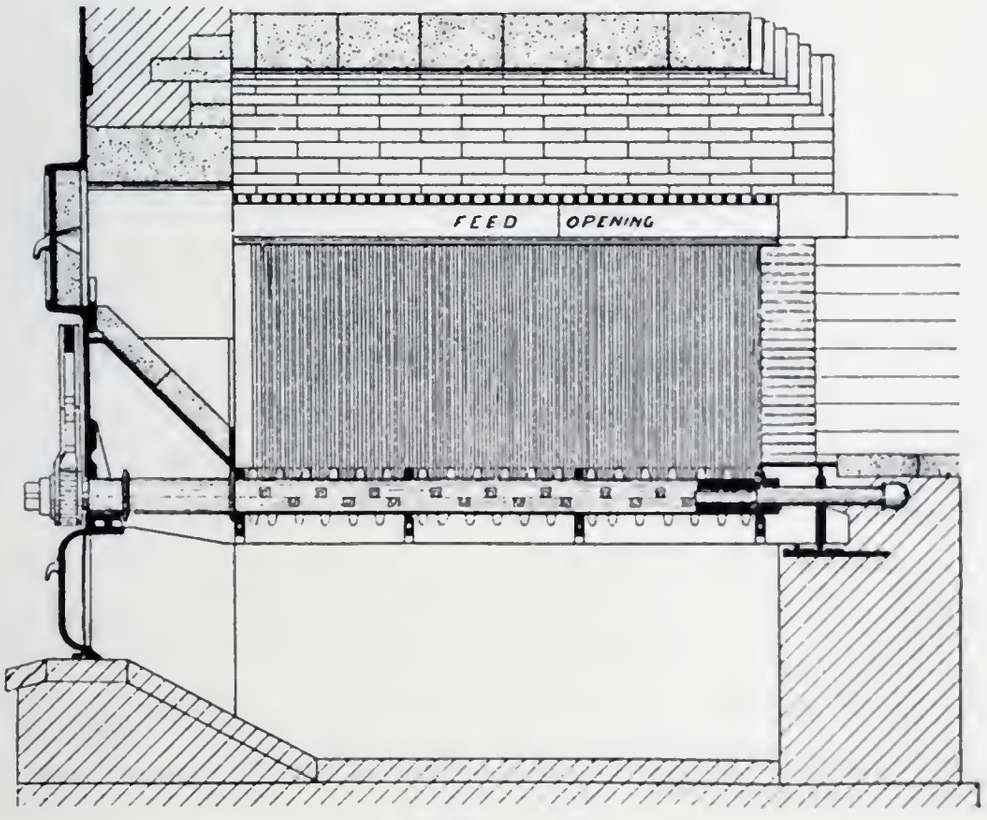
The first distinctly American invention of a mechanical stoker was the Murphy, brought out by Mr. Thos. Murphy, of Detroit, Mich., in 1878. Besides being the first American stoker, the Murphy was, I believe, the first invention in which a sloping grate surface was used. The sloping grate stokers of to-day can be divided into two classes, the side feed and the front feed. Of the side feed type we have two, the Murphy and the Detroit.

The Murphy stoker consists of two coal magazines, one at each side of the boiler, which form a portion of the boiler walls and extend back a depth depending on the grate area demanded. The bottom of these magazines is a flat plate built up of castings and steel angles in such a way that the top surface, where the coal lies, is cast iron, and directly beneath this is an air duct. Lying on top of this plate, called the coking plate, are inverted rectangular cast iron boxes having racks on their under side at each end. Beneath these boxes is a shaft extending the entire depth of the furnace and having segments of gears which mesh with the racks on the stoker boxes above. As this shaft is rotated through a small arc by means of an arm at the front of the fur-



TRANSVERSE SECTION.

Cross Section Murphy Improved Automatic Smokeless Furnace.

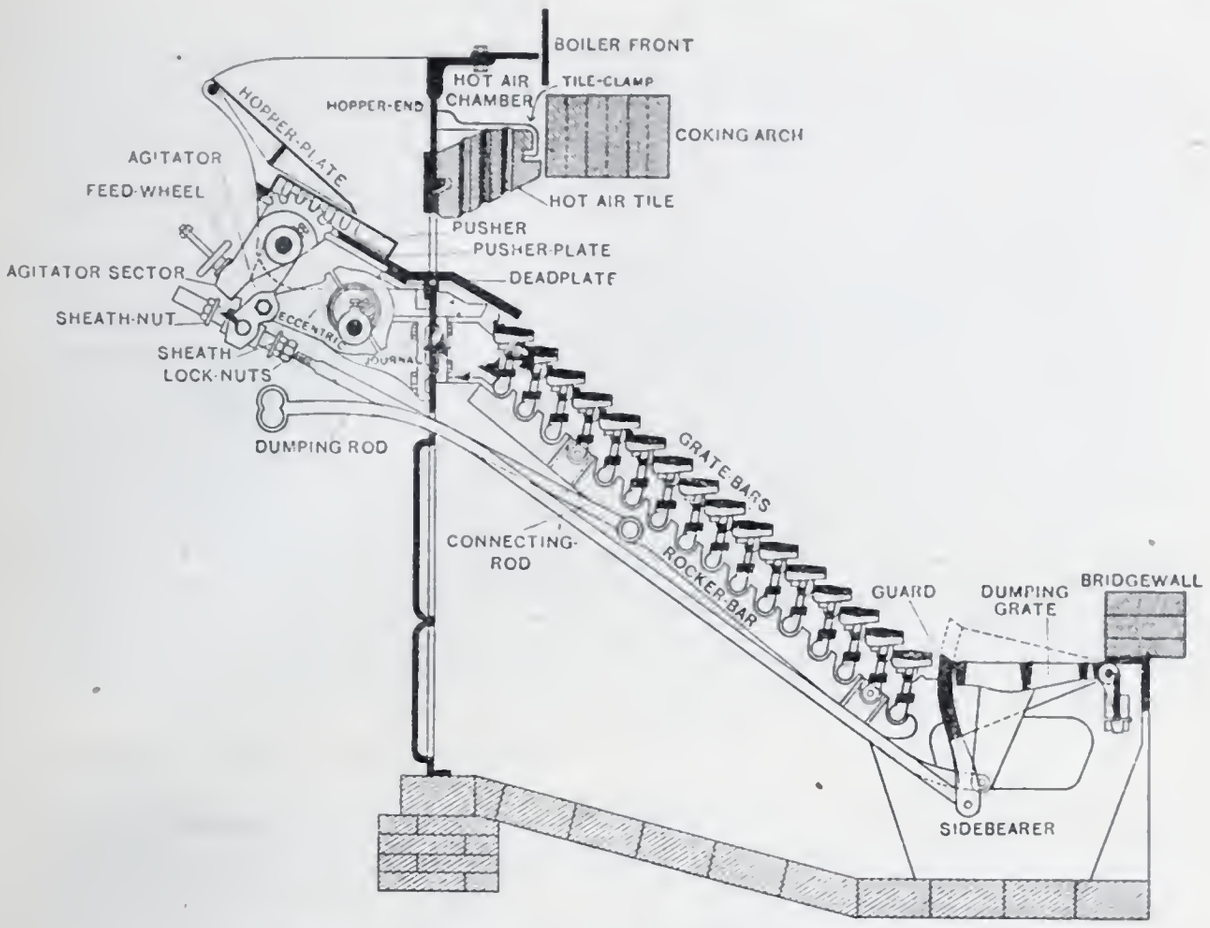


LONGITUDINAL SECTION

nace the stoker boxes are moved from side to side on the coking plate. As the box moves toward the centre of the setting a charge of coal is pushed out toward the edge of the plate. Resting against the edge of this plate and sloping down to the centre of the furnace at an angle of 40° to 45° are the grate bars. Running along the centre of the furnace is a heavy cast iron bearing bar, upon which the grates rest at their lower end. Supported by this bearing bar and taking the space between the lower ends of the grates is a hollow cast iron bar, having projections on its outer surface, which is made to rotate and grind the clinker into the ash pit below. The grates are straight castings and are made in pairs. One grate of each pair is stationary and the other is made to rise and fall about two inches at its lower end. Forming the inner side of the coal magazine and coming down to within five inches of the coking plate is a heavy ribbed casting known as the arch plate. Extending the entire depth of the grate surface and resting on the arch plates at each side is a firebrick arch. This arch is built with an air duct on its upper side, which is connected with the outside of the furnace by means of the passage in the coking plate already mentioned and with the fire space by means of small openings in the cast iron skew-backs, on which the arch rests. The object of these passages is to admit hot air above the coal at the point where the volatile matter is given off. The moving parts of the stoker are all actuated by a small engine standing at one corner and forming part of the stoker itself. This is made to drive a reciprocating bar extending across the front and connection is made to this by removable links. Any one part can be operated independent of all other parts. A distinctive feature of this type of stoker is the large coking space per square foot of grate area.

The above description covers the "Detroit" or "Morrow" furnace in all but one particular. In this stoker the coal is fed to the fire by means of a screw at each side.

In the front feed, inclined grate stokers, there is a coal hopper extending across the front of the boiler and having at its bottom a "pusher," which is given a reciprocating motion and pushes the coal out at the lower side of the hopper on to a dead plate, where it begins to ignite. As the coal is moved up into the fire space



Details of Construction of the Roney Mechanical Stoker.

it gives up its volatile matter and the solid portion is forced on to the sloping grate surface and burns there. Immediately back of the coal magazine, and extending from side to side of the stoker, is a short firebrick arch. These features are common to all makes of this class, but of course there is a variation in the details of construction. In the Roney, which is the most widely known of this class, the grates are so arranged as to form a series of steps, extending from the dead plate down to the dumping grate at the rear of the furnace. These grates extend from side to side of the stoker and by means of a mechanism at the front are made to assume the stepped and an inclined position alternately. This allows the fuel to gradually move down the grates and the refuse is finally deposited on the dumping grate, from which it is removed from time to time by the attendant.

The Brightman resembles the Roney very much. The grates are straight bars, having lateral lugs on each side, which overlap the lugs on the next bar when in position. These bars lie in the furnace in the direction of the axis of the boiler and each alternate

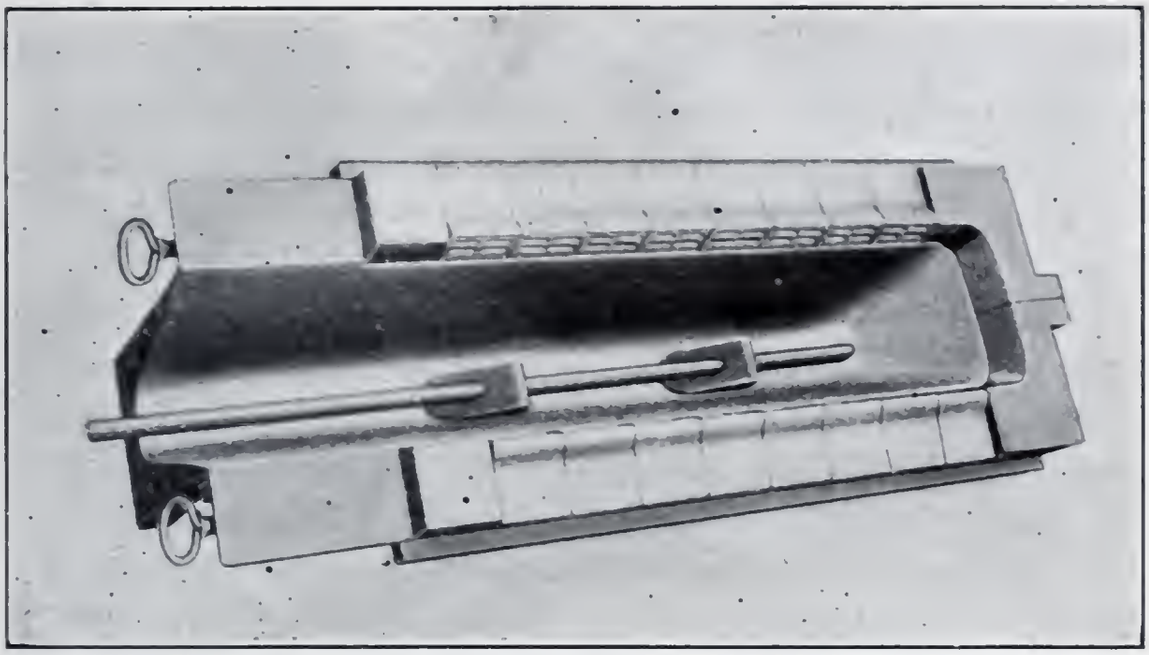
bar is stationary. The movable bar is given a slight horizontal motion and the fuel bed is thus agitated and made to move down the incline of the grates. At the rear of this incline is a clinker basket, into which the unburned material drops, and from which it must be removed by the operator.

The Wilkinson is another stoker of this class. The feature of this stoker is its grate bars and the means used to introduce air to the bed of fuel. Each grate is a hollow casting, having the top surface a series of steps. In the riser of each of these steps is a slot. At the upper end of each grate is placed a small steam nozzle, which serves to inject air into it, and so, by the slots, out into the bed of fuel. The grates are given a slight reciprocating motion, forcing the fuel down the incline. At the rear of the grates the unburned portion of the fuel falls into a closed ash pit.

There have been a number of other front feed stokers invented and placed on the market from time to time, some of which are now manufactured and others proved total failures from either an engineering or business standpoint. The ones that I have mentioned will cover the general features of construction, and to describe each one would be merely going into details.

All stokers so far mentioned can be brought under one head and termed over feed. Another type in which an entirely different principle is used is known as the under feed. In this case the fuel is forced up from undereneath and burns on top of a heap that forms in the middle of the furnace. A volume blower is used and air forced up through the heap of coal from openings in tuyer blocks which are located at the point where the fuel is supposed to give off its volatile matter. There are two makes of this class of stoker. In the Jones the coal is forced in beneath the heap in large charges by a steam ram. The American is a copy of the Jones in all but its feeding device. Instead of a ram a cone-shaped screw is used, being driven by a small reciprocating steam motor. All stokers of the under feed type must have the unburned refuse removed through the front of the furnace in the same manner as in hand firing.

In making a comparison between mechanical stoking and hand firing the most noticeable item is the smoke. With a properly constructed stoker used in connection with a stationary steam



"Jones" Underfeed.



"Jones" Underfeed.

boiler having its heating surfaces and passages for gases properly designed and constructed no smoke should issue from the stack whether the fires are being cleaned or not. Of the cloud of smoke hanging over the city of Greater Pittsburg about seventy-five per cent. comes from soft coal burned under stationary boilers. Of the smoke so made ninety-eight per cent. can be avoided and a saving of at least fifteen per cent. made in the cost of steam generated.

A point that has often been made against mechanical stokers is that they will not work a boiler to its full capacity. This may be true of a stoker in which the bed of fuel is not disturbed, allow-

ing the clinker to cement together and thus shut off the passage of air through the fire. But with a stoker which is self-cleaned, having its entire grate surface free from clinker at all times, there is no trouble in working a boiler from forty to sixty per cent. above its normal rating and securing good economy and smokeless combustion.

Here is a point that should be considered in first cost of plant. You may have a 500 H. P. boiler and decide to put in a certain stocker, because it costs less, that will not work the boiler to more than ten per cent. above rating. Another stoker, which may be a little more expensive to install, will work the boiler easily to twenty-five per cent above its rating, giving good economy, and, in case of a sudden demand, can be made to force it to fifty per cent. or more above rating. In both cases your boiler cost is the same, but in the first case you have but 550 H. P., while in the second you have 625 and can get 750 H. P. or more. It is very easy to see which is the cheaper when the cost per horse power development is considered.

As to the saving that can be made by the use of mechanical stokers, about the only reliable figures are those taken from the books of manufacturing concerns where an account is kept of the boiler house expense per unit of output. These figures can generally be obtained from the manufacturers themselves, but could hardly be embodied in a paper of this kind. When fuel alone is considered, the saving will seldom fall below fifteen per cent., and in large plants when the total cost of maintenance is considered, including labor and cost of repairs, the saving will be much above this.

In 1895 an investigation was carried on at the Ohio State University, which is of much value in this connection. A series of tests was made to determine the amount of saving that could be made by stoker firing over hand firing. The conditions were as near alike as possible in both cases. When the same high grade of coal was used for both methods a saving of sixteen per cent. was found in favor of the stoker. When a cheap grade of coal was used in the stoker and an expensive smokeless coal for hand firing a saving of fifty per cent. was shown in favor of the stoker. A number of other comparisons between different coals were made

and the results were embodied in the report of the University trustees of that year.

Our friends, the enemy, the strenuous advocates of hand firing, will point the finger of scorn at the many so-called total failures of mechanical stokers. But did they ever look into the cause of these failures? I will admit that there have been schemes of stoking invented that were not practical, but this is not saying that the whole subject is impractical. I have in mind now a case where an entire stoker equipment was condemned and thrown out because the arm on the damper shaft was not put on parallel with the damper. They tried to work the fires, supposing the damper to be open, and when they could not, of course, the stokers were at fault. They tried hand firing with the same result and then found the cause. Cases of this kind were formerly of frequent occurrence. A condition that is often met with is a boiler plant having good boilers and stokers and a stack sufficient to give ample draft. Connecting the boilers and stack will be a flue so constructed that the draft is almost entirely shut off. If your boiler plant is not giving you satisfaction, look it all over and the chances are, if you have been wise and bought a good stoker, that you will find the trouble at some other point.

The question to-day is not, shall we use a stoker, but what stoker shall we use. This is true no matter what the size of the plant may be.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The 234th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's house, 410 Penn avenue, Pittsburg, Pa., Tuesday evening, April 21, 1903, the President, Mr. C. B. Albree, being in the chair and 112 members and visitors present.

The meeting was called to order at 8:30 o'clock.

The minutes of the preceding meeting were read by the Secretary and approved by the Society.

The President stated that on account of so many other duties that Mr. Harry J. Lewis had requested to be relieved from the chairmanship of the Employment Department Committee, to which he was appointed at the regular March meeting, and that he had accordingly appointed Mr. Charles Worthington as chairman of the committee, retaining Mr. Lewis on the committee.

For the Board of Direction the Secretary read the names of the following applicants for membership who had been passed upon by the Board:

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY
EDWIN A. AMADEN,	Engineer in charge of Drg. Room, American Bridge Co. h., 427 Evaline St., Pittsburg, Pa.	J. K. Lyons, F. Engstrom, Emil Swensson.
G. W. BARNES,	Gas Engineer, Equitable Meter Co., 226 First Ave., Pittsburg, Pa.	C. F. Holdship, C. B. Albree, Ralph Albree.
R. O. BELLES,	Supt. Iron & Wire Works, Taylor & Dean, 205 Market St., Pittsburg, Pa.	C. B. Albree, Ralph Albree, S. M. Kintner.
FLORENCE C. BIGGERT, JR.,	Asst. Cont'g. Eng'r. United Engineering & Foundry Co. h., Idlewood, Pa.	K. C. Gardner, F. I. Ellis, G. W. Knotts.

JOHN P. BIGGERT, - Asst. Superintendent, -
With Pgh. Trolley Pole Co.,
Keystone Forge and Mach. Wks.,
h., 514 Shady Ave., Pittsburg, Pa
{B. M. Everson,
C. B. Albree,
C. W. Ridinger.

FRANKLIN B. BISSELL, Checker in Drawing Room
Standard Steel Car Co., Pgh., Pa.
h., 813 St. James St., Pittsburg, Pa., or 390 Linwood Ave, Buffalo, N. Y.
{Frank Irvin,
E. T. Parker,
J. E. Tesseyman.

GORDON M. CAMPBELL, Electrical Engineer, -
P. & L. E. R. R. Co.,
Pittsburg, Pa.
{A. R. Raymer,
E. S. McClelland,
T. S. Perkins.

JOHN N. CAREY, - Charge of Engineering Dept. -
G. L. Bollinger, 2817 Liberty Ave.,
h., Duquesne, Pa.
{Wm. Ahlen,
F. H. Gerwig,
J. M. Camp.

HAROLD CARPENTER, - Chief Draughtsman, -
Gas Wks. Construction Dept.,
Riter-Conley Mfg. Co., Pgh.,
h., Sewickley, Pa.
{L. W. Hildner,
H. M. Wilson,
C. W. Coffin

GEO. C. CARSON, Mining & Metallurgical Engr.
Residing at Redding, California.
Box 397, Pittsburg, Pa.
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B. E. Hobson,
C. W. Ridinger.

JOHN P. COLLINS, - Supt. Isabella Furnaces, -
American Steel Hoop Co.
Pittsburg, Pa.
{F. L. White,
H. J. Glaubitz,
James Scott.

GEO. B. DAMON, Engineer, Cahall Sales Dept., Pgh.
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J. F. Kuntz,
W. M. Judd.

DAVID H. DARLING, Secy. U. S. Battery Co. -
Of N. Y., Mfgr. of Storage Batteries,
Mgr. Pittsburg Office.
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J. L. Merrill,
E. R. Cate.

HARRY W. DOUBLEDAY, - Manager, -
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C. B. Albree,
C. W. Ridinger.

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City of Pittsburg.
City Hall, Pittsburg, Pa.
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C. B. Albree,
Ralph Albree.

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150 Frankstown Ave. & 1501 Arrott Bldg.,
Pittsburg, Pa.
{M. W. Brown,
J. K. Lyons,
Willis Whited.

EDWARD C. FITZGERALD, - In charge of -
Industrial Dept. of North School,
North School, Pgh., Pa.
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C. B. Albree,
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Braddock Mach. & Mfg. Co.
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C. L. Hastings,
F. B. Ward.

J. C. W. GRETH, - - Manager, - -
Water Softening and Purifying Dept., W. B. Scaife & Sons,
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{H. J. Glaubitz,
F. L. White,
Bruce Walter.

KING B. HUNTER, - - Sales Dept., - -
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E. Yawger,
J. P. Young.

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V. Bentner,
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3214-3230 Smaliman St., Pittsburg, Pa.
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Ralph Albree,
S. M. Kintner.

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H. E. Walters,
F. L. White.

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F. S. Martin,
C. B. Albree.

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Machine Co., Pittsburg Office,
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F. L. White,
Bruce Walter.

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Emil Swensson,
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P. Kemery,
A. J. Diescher.

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J. F. Kuntz,
L. P. Blum.

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34 Imperial Power Bldg., Pittsburg, Pa.
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Pittsburg Writing Machine Co., Kittanning, Pa.
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U. S. Steel Co., Engineering Dept.
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{M. P. Clark, C. W. Ridinger, F. A. Ensign.}

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Monongahela Bk. Bldg., Pittsburg, Pa.
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FLORIAN G. ROSS, - - Civil Engineer, - -
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HENRY C. SEIPP, Representing the W. S. Tyler Co.,
Cleveland, Ohio.,
608 Smith Block, Pittsburg, Pa.
{C. B. Albree, Ralph Albree, C. B. Connelley.}

WALLER L. SHAW, - - Inspector, - -
Robert W. Hunt & Co.
h., Glenshaw, Allegheny Co., Pa.
{F Engstrom, J. K. Lyons, E. Swensson.}

F. G. STIEREN, - - Manager, - -
The Wm. E. Stieren Co.,
543 Smithfield St., Pittsburg, Pa.
{F. Z. Schellenber, L. C. Weldin, F. Engstrom.}

B. E. TINSTMAN, - - - President, - -
Columbia Graphite Co.,
5819 Wellesley Ave., Pittsburg, Pa.
{B. E. Hobson, S. Diescher, C. W. Ridinger.}

ROBERT C. TURNER, - Electric Engineer, - h., 1908 Forbes St., Pittsburg, Pa. — E. L. Messler, J. R. Hauge, C. M. Mann.

LOUIS VIERHELLER, - Transitman, - Bureau of Surveys, Pgh., h., Walten Ave., 31st Wd., Pittsbnrg, Pa. — W. R. Browne, P. Vierheller, C. W. Ridinger.

CARLTON E. WARD, Asst. on Engineering Corps, E. & A. Div. Penna. Lines. h., 112 North Will St., New Castle, Pa. — M. P. Clark, C. W. Ridinger, F. A. Ensign.

FRANK L. WETTENGAL, - Draughtsman, - U. Engineering & Foundry Co., 1206 Penn Ave., Pittsburg, Pa. — K. C. Gardner, F. I. Ellis, G. W. Knotts.

THOS. J. WILKERSON, Asst. to Div. Manager, American Bridge Co., 51st St., Pittsburg, Pa. — F. Engstrom, J. K. Lyons, E. K. Morse.

T. B. WYLIE, - - - Gas Engineer, - - - Equitable Meter Co., 226 First Ave., Pittsburg, Pa. — C. F. Holdship, C. B. Albree, Ralph Albree.

TOTAL, 50.

THE PRESIDENT—Gentlemen, you have again heard a goodly list of names, and very little needs to be told you in regard to their positions. They are men of standing and men who will be a decided acquisition to our Society. A motion to have the Secretary cast the ballot for the election of these gentlemen is now in order.

It was moved and seconded that the Secretary cast the ballot electing the above named gentlemen as members of the Society.

Motion carried.

THE PRESIDENT—The next business will be the reports of the committees.

MR. BARNSLEY FOR THE RECEPTION COMMITTEE—Mr. President, I have little to report. I hope all that are here were at the Frick Building last Saturday night. The attendance was about 200, and that was followed by a dinner. I see a great many before me who were not present at the dinner to-night. I hope the next time we will have all present. I might say that the arrangements are well under way for a general excursion. Our announcement at the beginning of the year provided for one excursion during the summer, an excursion in which the members,

their friends and the lady members of the family could participate. The date is set for June 20th. That seems to be a date which would be the right one, as coming before the general vacation period; and while this notice may seem somewhat premature, I am hoping and expecting that everything now anticipated will be a reality on that date, June 20th. There are some other matters on the wing. One is a smoker and excursion at some nearby date, but I am not prepared to make an exact statement. Notices will be issued in due time when the arrangements have been perfected.

THE PRESIDENT—Gentlemen, you have heard the report of the Chairman of the Reception Committee, and having been his predecessor in that particular chairmanship, I can assure you that there is a lot of work involved in it. The present Committee has worked well, as all of us know who went to the Frick Building the other night, and some of us who went to the Frick Building to-night, to the restaurant for dinner, know. This was our first trial outside of the University Club, and was eminently successful. There were about 40 present, and if each one of you had been there and found out what we who were there know, I think we would see you all there the next time. We have arranged to have these dinners regularly at the Union Restaurant.

MR. J. M. CAMP FOR THE LIBRARY COMMITTEE—Mr. President, for the Library Committee, I can say that since meeting last fall, when we were forbidden to put the library in the only place we had for it, we have had it in the cellar. I suppose it will stay there until we can find room to place it.

THE PRESIDENT—In that connection I might say we have not as large a library as we had last fall by reason of the rats. In view of that it was decided to use two rooms to store such especially nice tid-bits of engineering literature as seemed particularly attractive to the rats.

MR. WORTHINGTON FOR THE EMPLOYMENT COMMITTEE—Mr. President, I have little to report. We have devoted our time to getting things into shape, so as to be of the most benefit to the Society. We would like to hear from both those who want men and those who are applicants for positions to be filled.

THE PRESIDENT—This Committee has charge of a branch of the work that would seem to be a very important feature of an Engineering Society's work. The opportunity given by these circulars to our members should be used by the members not only in securing positions, but in securing good men. I wish to say that since we have inaugurated this plan we have been requested by some very prominent concerns in Pittsburg to supply them with first-class men. If you have read over these rules adopted by the Employment Department, you will have noticed that the Engineers' Society does not assume the responsibility as to a man's fitness, and a question has come up as to when we are asked to recommend a man, whether that should be published. It is quite an acknowledgment of the Engineers' Society's position to be called upon to recommend men for such prominent positions. It seems to be the sentiment of the Board that where the Engineers' Society assumes to recommend a man, it will be left with the Board to make the recommendation, rather than the Society at large. It would work injury to the Society to recommend a man who was not suitable for a position, so in such cases all applications will not be published in the regular bulletin.

MR. DIESCHER FOR THE HOUSE COMMITTEE—All I can say is that we have tried to get a tenant, but so far have not succeeded.

THE PRESIDENT—Perhaps it is not known to the Society in general, but we have changed landlords. This house has been sold by Mrs. Foskett and we are now paying rent to another landlord, but our lease still holds good, so that our quarters here are secured to us. If the general meetings continue to be as well attended as in the past, I think it will be necessary to engage another hall for the monthly meetings. If one-fourth of our members were to come to our meetings it would be impossible to get them in this room. We have now about 850 members. It is up to the Program Committee to make the papers so interesting that we will have more than the one-fourth in attendance. We have had two or three meetings in which the room was so crowded that those coming late looked in and then went home. That is a sad state of affairs, but ordinarily, we do not have use

for a larger assembly room, and it might be policy to secure a larger room suitable for our regular meetings rather than to secure expensive quarters which would be used only two or three times a month.

We have a little unfinished business before taking up other matters—the official ratification of the formation of the Structural Section. It has been laid before you in the past. You all undersand the aims and objects of the Structural Section. It does not confine itself to any one line of structural work, but to structural work in its broad sense—concrete work, timber, steel and iron construction, and every variety of work which comes up under the head of structural work.

It was moved and seconded that the Structural Section be recognized as one of the regular sections of the Society. Motion carried.

THE PRESIDENT—It is with regret that I have to announce the death of three of our members. Two of these members died some time ago, but it was only recently that the board was informed of the fact. Mr. Kenneth Reinault, (?) and Mr. George Hodge, both members, died within the last several months. More recently one of our older members, a man who occupied a very high position in this city, was suddenly killed by a street car. I speak of Mr. W. W. Card, who was identified with the Westinghouse Air Brake Co. from its inception. As is usual in such cases, the President will appoint a committee to draw up resolutions if acceptable to the Society. I name for that committee Mr. E. B. Taylor, one of our former presidents, and Mr. Charles F. Scott, my immediate predecessor, both of whom were well acquainted with Mr. Card. I hope they will draw up resolutions and present them at our next regular meeting.

You have perhaps noticed the announcement of a general meeting next Thursday, the date of meeting of our Chemical Section, with the Pittsburg Section of the American Chemical Society. This is the culmination of a step that your former President, Mr. Scott, had earnestly at heart, and we trust that it will be but the commencement of other similar amalgamations. The main object of the Engineers' Society is to bring together

engineers in different lines of work, and if there are two organizations in the city working along the same lines, it certainly seems best that they should club their issues and thereby accomplish more good to a greater number. This, I think, is the inauguration of such general meetings, and it is to be hoped that some of the other sections will succeed in uniting with some of the larger societies, so that we will work together for our mutual good.

The Chemical Section has brought to our attention the proposed visit to Pittsburg, in 1904, of a society of chemical industry. The Society of Chemical Industry is an international society of very high standing. Heretofore its meetings have generally been held in England, and it is proposed this year to have the meeting in New York, and in consequence a large number of its foreign members will come to this country for the meeting in New York, at which I understand an American is to be elected president of the society. It is proposed to have excursions to the various large cities in this country, something similar to the excursion of the Iron & Steel Interests when they visited nearly all the large cities in this country. Among other points of interest Pittsburg is placed, and it is proposed to have the Engineers' Society unite with the Chemical Section and American Chemical Society in giving them a proper reception when they arrive in Pittsburg next year. In order to give them a proper reception it is necessary to have funds, and the funds will have to be raised for their entertainment while here. The committee is to see that they see our mills and that they are properly taken care of at the hotels. The committee should properly embrace some of our members so that if it is the wish of the Society, a committee of ten will be appointed, five of which will be named by your President and five by our Chemical Section, to undertake the matter of receiving these foreign visitors. This committee will be appointed later.

It was moved and seconded that the committee be appointed as the President suggested. Motion carried.

Mr. C. B. Scott—What you state about the chemists brings to my mind some experiences of mine during the past week. The attendance numbered 250 at the meeting in New York during the

past week. They had papers read and a dinner, and Saturday evening there was a very pleasant evening entertinment at the Chemists' Club. During the evening there was an address by the President and some interesting electrical apparatus shown and a general and good time smoker followed. I learned something of the Chemists' Club through Dr. Jermy and Prof. Chandler. I was very much interested in the way they go at things. They take great pride in their library and have a plan on hand to have everything in duplicate, one book always to stay in its place and another to go wandering out over the country when it may be called for. They have men available for answering inquiries. You can write them on any question and it will be taken up and translations made if necessary and sent for a small fee. They have a monthly meeting ending up with a smoker afterwards. There seems to be a very strong German element there, with their technical knowledge and their ideas of a good time, so you see we will have men here who are used to extending hospitalities. One word about this association with the National Society, as I stated a little while ago at dinner. I heard just a few days ago that the St. Louis Engineers' Club is trying to get some line of relationship, effective working relationship, with the National Societies. They have appointed one of their mechanical and electrical members to take it up with the National Society, and to ask the Boards of Direction whether they cannot propose some means by which there can be a close association between the local society and the National Society. There are difficulties to overcome, but the principle is right, and if it is technically all right, engineers should be able to work out some practical scheme that would lead to the results desired.

The President—Gentlemen, the more we look into the fields of work that are open to an Engineering Society, the more we find we have a very broad field. We do not want to make haste too rapidly, but there are several lines which have been considered, some of which, I think, would be of very great advantage, which, it is hoped, we will inaugurate shortly, or as soon as it seems feasible.

One more point I wish to allude to, and that is in regard to

the postal cards which, doubtless, you have all received. The principal idea in sending out these postal cards was to ascertain how many we could depend upon for membership in the different sections. We thought we would probably find fifty or seventy-five men out of our membership of some 850 who would like to enroll themselves as members of this or that section. Our surprise has been considerable, as about three-fourths of the cards that came in stated that the members wanted to belong to both sections.. As to the Chemical Section we do not have so many responses, as it is not of so general interest. It is probably over the heads of the majority of our members, but as to the structural and chemical sections, about 500 cards out of the total membership have come back, which is a good proportion, and out of those, about three-fourths desired to be on both sections. Now what does that indicate? It indicates two or three things that are worthy of observation.

In the first place it indicates that each individual that sent in his name to be enrolled wished to know what was going on in this world. It indicates also that the character of the meetings of these sections has been of such nature as to attract our members. Those of you who have attended the meetings know, without my telling you, and those who do not, only need to go to the meetings to find out. At the last meeting of the mechanical section the room was about as full as it is now. The board have about decided that the only way to take care of them properly is to send notices to every member of the Society in advance of these meeting three or four days, giving the subject. They will be published in the regular monthly bulletin, but the regular monthly mail is often laid on your desk and you forget all about it, so that the postal cards will be sent to all the members as a reminder.

Is there any other business to be presented before we take up the paper of the evening?

Unfortunately Mr. Gow was called to New York on business and will not be here to read his own paper. I am very sorry for this, as Mr. Gow is an authority on the subject of manufacturing fuel gas, and it would have been a very great pleasure to hear him read his own paper and have him join in the discussion. How-

ever, he has appointed a very worthy representative, Mr. Flint. The question is one of great importance and will become more and more important every year. The perfection of the gas engine in recent years has led to a demand for cheap gases for fuel. In Germany they utilize the blast furnace gases, and it seems to be generally conceded that it is possible to manufacture fuel gas almost equal to natural gas in its heating power, which will be used instead of coal.

I have a little note here from Mr. Scott, suggesting that on each postal card notice sent out there should be a calendar of the coming meetings. I think that is a very good suggestion, and one which we will probably adopt.

The paper of the evening, "Commercial Gases for Power Purposes," by Alexander M. Gow, was read by Mr. Flint.

Mr. Flint stated that on account of the length of the paper he would omit certain parts of same, which would be published in the proceedings.

COMMERCIAL GASES FOR POWER PURPOSES.

BY ALEXANDER M. GOW.

A FEW WORDS CONCERNING GAS.

The following pages are for the general information of those users of gas who desire to obtain a speaking acquaintance with the subject. They are written with special reference to the use of gas in gas engines. Technical refinements have been avoided. Values are given in round numbers, easy to remember, not always scientifically accurate, but sufficiently so for purposes of ordinary calculations.

For further information the reader is referred to the extensive literature of the subject; this is but the alphabet.

THE CONSTITUENTS OF COMMERCIAL GASES.

By the term "gas," as used commercially, a mixture of various gases is generally understood. The relative proportions in which these constituent gases appear in a commercial gas depend upon the method of manufacture and the raw materials used. The methods of manufacture are many. The raw materials consist of air, water and any carbonaceous matter, such as coal, coke, wood, oil or garbage. Given these raw materials and various commercial gases can be produced which differ from each other in the proportions of their constituent gases. These constituent gases are as follows: Hydrogen, oxygen, nitrogen, carbonic oxide, carbonic acid, marsh gas and olefiant gas. Sulphur also appears in small quantities, and is an objectionable impurity. For the sake of brevity and convenience certain symbols have been adopted to designate these gases. The symbol of a chemical combination tells at a glance. the proportions of the different elements that have united to form it. A knowledge of the atomic and molecular weights of the elements makes it a simple matter of arithmetic to calculate how

many pounds of each element are in a given weight of the combination. For instance, the symbol for carbonic acid is CO_2. This shows that one atom of carbon (symbol C), has united with one molecule of oxygen (symbol O_2), to form one molecule of carbonic acid (CO_2). The atomic weight of carbon is twelve and the molecular weight of oxygen is thirty-two. Using the symbols in the form of an equation:

$$C + O_2 = CO_2 \text{ or in pounds,}$$
$$12 + 32 = 44$$

That is to say, twelve pounds of carbon unite with thirty-two pounds of oxygen and form forty-four pounds of carbonic acid. Or, dividing through by twelve, one pound of carbon unites with two and two-thirds pounds of oxygen to produce three and two-thirds pounds of carbonic acid. The symbol of olefiant gas is $C_2 H_4$. Two atoms of carbon have united with four atoms (or two molecules) of hydrogen. Expressing this in symbols:

$$2C + 2H_2 = C_2H_4, \text{ or in pounds,}$$
$$24 + 4 = 28,$$

showing that twenty-eight pounds of olefiant gas contain twenty-four pounds of carbon and four pounds of hydrogen. With this explanation of the use of symbols let us consider the characteristics of the various gases, which mixed together, go to make up a manufactured gas.

Hydrogen. Atomic symbol, H. Atomic weight, 1. Molecular symbol, H_2. Molecular weight, 2. Hydrogen is so light that it has been adopted as the standard by which to weigh all other elements. When the atomic weight of hydrogen is given as one, and that of oxygen as 16, it means that for equal volumes at the same temperature and pressure, oxygen is sixteen times as heavy as hydrogen. In the case of both oxygen and hydrogen two atoms of each combine to form one molecule of each, but the ratio of weights remains the same, sixteen to one. Hydrogen uniting with oxygen burns with a blue flame, producing water in the form of water vapor. The formula for this reaction is:

$$H_2 + O = H_2O, \text{ or in pounds,}$$
$$2 + 16 = 18$$

Two pounds of hydrogen burn with sixteen pounds of oxygen to form eighteen pounds of water. The formula also shows the relative volume of each gas that has entered into combination. Two cubic feet of hydrogen unite with one cubic foot of oxygen. Of course the volume of the water vapor produced will depend upon its temperature, and if it be condensed to water there will be but a small quantity produced by burning two cubic feet of hydrogen with one cubic foot of oxygen. But the weight of water is of course equal to the combined weights of the gases that formed it. The heat evolved by burning one cubic foot of hydrogen with one half a cubic foot of oxygen is sufficient to raise the temperature of three hundred and twenty pounds of water one degree Fahrenheit. A British thermal unit is the amount of heat required to raise one pound of water one degree Fahrenheit. The abbreviation used is B. T. U. Consequently hydrogen has a calorific or heating value of 320 B. T. U. per cubic foot. Now the atmosphere, which is the source of oxygen for combustion, contains twenty cubic feet of oxygen to eighty cubic feet of nitrogen. But for purposes of combustion the oxygen cannot be separated from the nitrogen. Conesquently, for each cubic foot of oxygen required four cubic feet of nitrogen go along, or five cubic feet of *air*. So when two cubic feet of hydrogen are burned with one cubic foot of oxygen, five cubic feet of air must be supplied. This is the theoretical requirement; as a question of fact, to insure complete combustion in practice, it is necessary to supply more oxygen, consequently more air, than this theoretical amount. In most commercial gases hydrogen appears either as free hydrogen or combined with carbon to form what is known as a "hydrocarbon." The term "hydrocarbon" covers an almost unlimited number of compounds, gaseous, vaporous, liquid and solid. In general a "heavy hydrocarbon" contains more carbon than a "light hydrocarbon." As a rule if a "heavy hydrocarbon" is subjected to heat, in the absence of oxygen, a "light hydrocarbon" is driven off and carbon deposited. The application of heat to a "heavy hydrocarbon," either solid or liquid, may evolve "lighter hydrocarbons" both vapors and gases, and a residue of a solid "heavy hydrocarbon" or pure carbon may be left behind as a final product. This process of subjecting a "heavy hydrocarbon" to

heat in the absence of oxygen, to evolve "lighter hydrocarbons" is called distillation. Oil gas is made by this process from crude oil. Crude oil is a mixture of various "heavy hydrocarbons." When heat is applied "lighter hydrocarbons" in the form of gases and vapors are evolved. And if the heat be sufficiently high these gases and vapors may be still further broken up into free hydrogen and carbon, which latter will be deposited as free carbon or lamp black. When hydrogen, (H_2) appears in the analysis of a commercial gas it is to be considered as a desirable constituent, owing to its calorific value and the ease with which it burns to water.

Oxygen. Atomic symbol, O. Atomic weight, 16. Molecular symbol, O_2. Molecular weight, 32. One-fifth of the volume of the air is oxygen, O_2. It combines with nearly all other elements and heat is evolved by the combination. It is the "supporter of combustion." In commercial gases it appears only in small quantities as free oxygen (O_2) rarely more than two or three per cent. But combined with carbon it forms a large constituent of most of them, appearing in carbonic acid, (CO_2) and in carbonic oxide (CO). When free oxygen (O_2) appears in the analysis of a gas it is not to be considered as having any heating value. To the extent that it appears just that much less oxygen will have to be supplied from the air to burn the gas.

Nitrogen. Atomic symbol, N. Atomic weight, 14. Molecular symbol, N_2. Molecular weight, 28. About eighty per cent. of the volume of the atmosphere is nitrogen (N_2). It is extremely inert. In this respect it is the opposite of oxygen. Only with difficulty can it be made to combine with other elements. It is evident that when air is one of the raw materials used in gas making that the gas made must contain the inert nitrogen (N_2). When it appears in the analysis of a commercial gas it is to be considered only as a diluent, having no heating value, retarding the combustion of the other gases and reducing the calorific value of the whole.

Carbonic Acid. Symbol, CO_2. Molecular weight, 44. Also known as carbon dioxide and carbonic anhydride. When carbon and oxygen are brought together at sufficiently high temperature to start combustion they burn to carbonic acid (CO_2). Heat

must be supplied to start the union, but once started heat is liberated. The combustion of one pound of carbon to carbonic acid evolves 14,500 B. T. U. Expressed in symbols:

$$C+O2=CO2$$
$$12+32=44, \text{ or, dividing by twelve,}$$

One lb. Carbon +2-2/3 lbs. Oxygen=3-2/3 lbs. $CO2$=14,500 B. T. U.

When carbonic acid appears in the analysis of a mixed gas it is to be considered as valueless as nitrogen. It has no power to produce heat. It is burnt carbon, a dead, inert gas, acting only as a diluent and reducing the calorific value of the mixture.

Carbonic Oxide. Symbol, CO. Molecular weight, 28. Also known as carbon monoxide. As said before, when carbon and oxygen combine carbonic acid, $CO2$, is formed. But if there is an excess of carbon or what is the same thing, an insufficiency of oxygen, then carbonic oxide, CO, is formed. Expressed in symbols:

$$C+O=CO, \text{ or, in pounds,}$$
$$12+16=28, \text{ or, dividing by twelve,}$$

one pound of carbon unites with one and one-third pounds of oxygen to form two and one-third pounds of carbonic oxide, and 4,250 B. T. U. are liberated by this union. But we saw previously that one pound of carbon burnt to carbonic acid liberates 14,500 B. T. U. By comparison, then,

1 lb. Carbon +2-1/3 lbs. Oxygen=3-2/3 lbs. C.2=14,500 B.T.U.
1 lb. Carbon +1-1/3 lbs. Oxygen =2-1/3 lbs. CO=4,250 B.T.U.

Difference in burning 1 lb. Carbon to CO and $CO2$ 10,250 B. T. U.

It is thus evident that if one pound of carbon be burnt with an insufficient supply of oxygen and the resulting carbonic oxide not burnt, over two-thirds of the heating value of the carbon is lost. This frequently happens to a greater or less extent when coal is improperly burnt under boilers with an insufficient supply of air, owing to poor draft, bad firing or improper design of boiler furnace. It is not a difficult matter to make an analysis of the gases passing up the stack to determine the percentage of carbonic acid, carbonic oxide and free oxygen. If there is any carbonic oxide it is positive evidence of a useless waste of fuel.

It has been explained that carbonic acid ($CO2$) is the result

of the complete combustion of carbon; whereas carbonic oxide (CO) is the result of its partial combustion. It follows therefore that carbonic oxide can be burnt to carbonic acid. In formula, $CO+O=CO_2$. This union evolves heat. But if, at high temperature, carbonic acid (CO_2) is brought into contact with carbon the reaction is reversed and one cubic foot of carbonic acid (CO_2) takes up more carbon to form two cubic feet of carbonic oxide (CO). Expressing this in formula

$$CO_2+C=2CO$$

But this is the reverse of combustion. Consequently this reaction in place of evolving heat requires heat. It cannot take place unless heat is supplied. A reaction that evolves heat is said to be *exothermic*. One that absorbs heat is said to be *endothermic*. The combination of carbon and oxygen to form carbonic acid is therefore exothermic; while the combination of carbonic acid and carbon to form carbonic oxide is endothermic. Consequently, if carbonic acid (CO_2) be passed into a red hot body of coke the carbonic acid will be transformed into carbonic oxide (CO). Heat will be rapidly absorbed and the body of coke cooled down until a temperature of about 1,500° F. is reached, when the reaction will cease. It follows, of course, that if the carbonic oxide thus formed be again given more oxygen it will burn to carbonic acid and the absorbed heat again liberated. In a gas producer the oxygen of the air entering the bottom of the fuel bed is first converted into carbonic acid with the liberation of much heat at high temperature. But as this hot carbonic acid passes up through the fuel bed it meets more carbon and is converted into carbonic oxide (CO). This will be discussed further under the head of producer gas. Carbonic oxide is a very poisonous gas, producing asphyxiation when inhaled. It is a desirable constituent of a commercial gas. One cubic foot burnt with one-half cubic foot of oxygen produces one cubic foot of carbonic acid. This union evolves heat. Carbonic oxide has the same clorific value as hydrogen, 320 B. T. U. per cubic foot. Consequently in a commercial gas it may be considered as having equal value with hydrogen.

Marsh Gas. Symbol, CH_4. Molecular weight, 16. Also known as methane. This gas is given off in variable quantities

when bituminous coal or crude oil is subjected to heat. It is also the main constituent of natural gas and forms a large percentage of "fire damp" in coal mines. When heated in the absence of oxygen it readily breaks up into carbon and hydrogen, the carbon being deposited as lamp black or appearing as black smoke. If sufficient oxygen be present the carbon burns to carbonic acid and the hydrogen to water. If there be not sufficient oxygen present the hydrogen will burn first and some of the carbon will be deposited, while the gas will burn with a smoky flame. The peculiar pungent odor so often noticeable when natural gas is used for heating is due to the incomplete combustion of marsh gas. The remedy in such cases is to supply more air or so arrange the burner that a more intimate mixture of air and gas shall be obtained. Marsh gas has a very high calorific value, the combustion of one cubic foot evolving 1,000 B. T. U., or more than three times as much as the same volume of hydrogen or carbonic oxide. Consequently it is a desirable constituent of a commercial gas. It does not burn as rapidly as hydrogen or carbonic oxide because before it can be burnt it must be broken up into its constituents carbon and hydrogen. This fact makes it a particularly desirable constituent of a gas for use in gas engines. Its presence retards the combustion of the entire mixture and lessens the liability to pre-ignition and back firing.

To burn one cubic foot of marsh gas there are required two cubic feet of oxygen, as will be seen by the formula:

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$

But as air is one-fifth oxygen, ten cubic feet of air are required. In practice it is always necessary to supply more than the theoretical quantity of air to insure complete combustion. Practice has shown that at least twelve cubic feet of air should be supplied for each foot of gas and in many cases this amount should be increased to fourteen. Marsh gas burns with a slightly luminous flame, but its luminousity is not sufficient to warrant its distribution as an illuminating gas.

Olefiant Gas. Symbol, C_2H_4. Molecular weight, 28. Also known as ethylene. This gas, like marsh gas, is evolved when bituminous coal or oil is subjected to heat. It burns with an in-

tensely luminous flame. If the luminosity of marsh gas be taken as five candle power the luminosity of olefiant gas is seventy candle power. Consequently a mixture of gases that burn with a blue or slightly luminous flame can be rendered luminous by the addition of a few per cent. of olefiant gas. It has a calorific value of 1,600 B. T. U., or five times that of hydrogen. Like marsh gas it burns to carbonic acid and water, but as it contains more carbon than does marsh gas, more oxygen is required to burn it. One cubic foot of olefiant gas burnt with three cubic feet of oxygen produces water vapor and two cubic feet of carbonic acid. By formula:

$$C_2H_4+3O_2=2CO_2+2H_2O, \text{ or, by weight,}$$
$$28 +96 =88 \quad +36$$

That is to say, twenty-eight pounds of olefiant gas uniting with ninety-six pounds of oxygen produce eighty-eight pounds of carbonic acid and thirty-six pounds of water. Of course it is to be understood that the products of combustion in addition to the carbonic acid and water vapor formed must contain four cubic feet of nitrogen for every cubic foot of oxygen supplied. In the analysis of a commercial gas olefiant gas appears only in small quantities, rarely more than six per cent. On this account it cuts but little figure in a gas used for power purposes, but it is an essential in a mixed gas distributed as an illuminating gas.

Illuminants. Frequently in the analysis of a mixed gas there is specified a certain percentage of "illuminants." Generally olefiant gas is included in the "illuminants." As generally used the term is applied to those gases and vapors that render the gas flame luminous. It frequently happens that "illuminants" are not gases at all, but vapors which will condense to liquid form at a sufficiently low temperature. They form but a small percentage of the volume of any commercial gas.

COMMERCIAL GASES USED IN GAS ENGINES.

As said before commercial gases differ from each other in the relative proportions of the constituent gases. The names given to these different mixed gases are derived from the method of manufacture and the raw materials used. We will consider the

method of manufacture and the characteristics of the following commercial gases:

Bench Gas. Made by heating coal in retorts set in "benches."

Water Gas. Made by decomposing water in the presence of carbon.

Producer Gas. Made in a "producer" from air, steam and carbon.

Oil Gas. Made by subjecting oil to heat.

Carburetted Water Gas. Made by the addition of oil gas to water gas.

Coke Oven Gas. Made by heating coal in a "by-products" coke oven.

Blast Furnace Gas. Made in a blast furnace during the operation of smelting iron ore to pig iron.

Natural Gas. Made by Nature, operating under a secret process.

The name "illuminating gas" does not signify the method of manufacture or the raw materials used. Both bench gas and carburetted water gas are distributed as "illuminating gas." The name "distilled gas" is applicable to bench gas, coke oven gas and oil gas. The name "coal gas" was originally applied to bench gas exclusively, but as bench gas, producer gas and coke oven gas are all directly derived from coal the name has lost its original significance.

Bench Gas. When bituminous coal is heated in a closed retort the volatile constituents are driven off in the form of gases and vapors. After a sufficient length of time there remains in the retort a body of coke. Before the gases thus evolved can be distributed for use or burned in a gas engine the heavy vapors must be removed, for if not they will condense in the form of tar and cause clogging of pipes, sticking of valves and fouling of cylinders. Upon leaving the retorts the gases and vapors pass through the hydraulic main. This is simply a water seal that serves as a valve to prevent a flow of gas back into the retort when it is open to be re-charged. In the hydraulic main the gases

and vapors bubble through a few inches of water and a portion of the vapors are condensed into tar. The gases and uncondensed vapors then pass to the condenser, where they are cooled. Here more of the vapors condense to tar. The gases now cool, and partially but by no means wholly, freed from tarry vapors pass to the exhauster. This is a positive blower and serves to draw the gases from the retorts, through the hydraulic main and condenser, and force them along through the scrubber, the purifier and into the holder ready for distribution. The purpose of the scrubber is to remove all the tarry vapors left, together with the ammonia; for as the gases leave the retorts they contain a certain amount of ammonia, which in addition to being an objectionable impurity in the gas volume is well worth saving as a by-product. Various types of scrubbers are in use, but the principle involved is to bring the gases into contact with wet surfaces and cause an intermingling of water and the gases, The tar sticks to the surfaces and the water absorbs the ammonia. From the scrubber the gases, now freed from tarry vapors and ammonia, pass to the purifier, where carbonic acid and sulphur compounds are removed. The carbonic acid is objectionable because it seriously reduces the illuminating power of the gas and has no heating value. Sulphur compounds are objectionable because of the offensive odor when the gas is burned. Lime and iron oxide are the materials mainly used for the purification of gas. For a full discussion of purification and the chemical reactions involved, together with a description of the various scrubbers and other apparatus, the reader is referred to the many works on the subject.

The volatile constituents of the coal first driven off from a freshly charged retort are quite different from those evolved during the last stages of the distillation process. But inasmuch as several retorts are set in one "bench" and charged successively, the gas that goes to the holder has a uniform composition. This composition will depend very largely upon the coal used and the temperature of the retorts.

The following may be taken as a typical analysis of bench gas made from a good grade of gas coal; composition by volume:

Hydrogen	H_2	46.00%	Combustible, 97.00%
Marsh Gas	CH_4	40.00%	
Carbonic Oxide . .	CO	6.00%	
Olefiant Gas	C_2H_4	5.00%	Incombustible, 3.00%
Carbonic Acid . . .	CO_2	.5 %	
Nitrogen	N_2	2.00%	
Oxygen	O_2	.5 %	
		100.00	

Using the calorific values before given for the constituent gases the above mixture has a calorific value of 668 B. T. U. per cubic foot. For combustion there are required 1.21 cubic feet of oxygen or 6.05 cubic feet of air, per cubic foot of gas. In practice, however, at least eight cubic feet of air should be supplied to insure complete combustion. Less than this amount will cause the gas to burn with a smoky flame and there will be more or less carbon deposited as lamp black. The products of combustion are of course water vapor, carbonic acid and nitrogen. The exact composition of gas distributed for illuminating purposes is governed by all sorts of legislation aimed at prescribing the permissible amounts of carbonic acid, carbonic oxide, sulphur and "illuminants."

Bench gas gives very satisfactory results when used in gas engines. Originally all gas distributed was made by this retort process. But about the year 1880 the water gas process came into use and to-day the general practice of illuminating gas companies is to distribute a mixture of bench gas, water gas and oil gas; water gas and oil gas together being designated carburetted water gas.

Water Gas. When steam and carbon are brought into intimate contact at high temperature the steam is decomposed into oxygen and hydrogen; the oxygen thus liberated combines with the carbon to form carbonic acid and carbonic oxide, while the hydrogen remains free. The relative amounts of carbonic acid and carbonic oxide formed will depend upon various conditions, but it is evident that the most desirable conditions are those that favor the largest production of carbonic oxide and the smallest of carbonic acid. If a body of coke, in a suitable vessel called a "producer" be blown by a blast of air until white hot, and then the blast shut off and steam turned on, water gas will be formed.

The body of coke will be rapidly cooled, for heat is absorbed by the breaking up of the steam into oxygen and hydrogen. Inasmuch as the union of oxygen and hydrogen to form water evolves heat, it follows that the conversion of water into oxygen and hydrogen must absorb heat. Consequently the formation of water by the union of oxygen and hydrogen is said to be exothermic. It evolves heat. And the opposite reaction is endothermic. It absorbs heat. And the amount of heat evolved must be equal to the amount of heat absorbed. But, as stated before, when steam is broken up in the water gas process the liberated oxygen combines with the carbon. But this union evolves heat; that is to say it is exo-thermic. But more heat is absorbed by the breaking up of the steam than is evolved by the union of its oxygen with carbon. Consequently the thermal result of the two reactions will be endothermic; the body of coke will thereby be cooled down. It becomes necessary, therefore, to store some more heat in the body of coke. This is done by shutting off the steam and blowing the coke body with air, preparatory to another steaming.

These successive "blowings" and "steamings" constitute the "intermittent water gas" process. Usually in practice two producers are used, one being blown hot while the other is steaming. A suitable arrangement of valves is provided, so that the water gas made while steaming shall be kept separate from the gases thrown off while blowing hot with air. Almost numberless are the modifications of these fundamental ideas that have been made. The coke, except what appears in the ash and clinker, is wholly converted into gas. Theoretically pure water gas would consist of half carbonic oxide and half hydrogen and have a calorific value of 320 B. T. U. per cubic foot. But theoretical conditions are not obtained in practice and a typical analysis of water gas made from bench gas coke is a follows; composition by volume:

Hydrogen	H_2	48.00%	Combustible, 88.00%
Marsh Gas	CH_4	2.00%	
Carbonic Oxide . .	CO	38.00%	
Carbonic Acid	CO_2	6.00%	Incombustible, 12.00%
Nitrogen	N_2	5.50%	
Oxygen	O_2	.50%	
		100.00	

Using the calorific values before given for the constituent gases the above gas contains 295 B. T. U. per cubic foot. It will be noticed that it contains no olefiant gas (C_2H_4) nor "illuminants;" consequently it burns with a blue flame. In fact sometimes water gas is designated as "blue gas." As compared to bench gas it is low in marsh gas (CH_4) and high in carbonic oxide (CO). Had it been made from pure carbon it would contain no marsh gas at all. What little it does contain shows that the bench gas coke from which it was derived had not been completely coked. The large percentage of carbonic oxide (CO) makes it very poisonous, and for a time there was a very great prejudice against its use. But that prejudice has been largely overcome. It is not well adapted for use in gas engines, as it burns so rapidly and is so "snappy" that troubles arise from back-firing and pre-ignition. Inasmuch as it is made from coke and steam, it contains no tar or heavy vapors, and consequently little scrubbing is required to render it clean enough for distribution. To change its flame from a blue to a luminous one there may be added to it from five to ten per cent. of "illuminants." This is done by the use of oil, naptha, "tar oil" or some similar heavy hydro-carbon which, when heated, will evolve illuminating gases and vapors. Many different arrangements are in use to accomplish this end. The resulting mixture is known as carburetted water gas. Over half the illuminating gas sold in the United States is carburetted water gas. So that a modern plant for the manufacture of illuminating gas may consist of the benches of retorts for the distilling of bench gas from coal; gas producers in which water gas is made from the coke derived from the retorts and carburetting apparatus for the enriching of the water gas with oil gas. As explained, it is necessary in the operation of a water gas producer to periodically stop steaming and blow hot. The gases passing off during the heating blow consist of the nitrogen of the air, carbonic acid and carbonic oxide with some free oxygen. This "lean" gas mixture may be used to a greater or less extent to raise the steam for the steaming operation. Or it may be used to furnish the heat necssary to volatilize the oil for enriching. Naturally the water gas process lends

itself to an almost infinite number of modifications. Some blow *up* through the fuel; some blow *down*; some steam upward; some steam down; some blow to produce the highest percentage of carbonic acid in the "lean" blow gas; some blow to produce the lowest percentage of carbonic acid and the highest percentage of carbonic oxide, in order that these lean, blow gases may be burned to advantage under boilers or in regenerative chambers. Others operate so as to produce a mixture of the water gas and the best of the blow gas. It is out of place here to discuss the relative merits of these different methods of operation. Suffice it to say that by the water gas process COKE may be converted into water gas and the gas from the blow; the water gas may or may not be enriched with oil gas to increase its luminosity; the gas produced by the blow may be used in various ways.

The question arises here: Why cannot bituminous coal be used direct in the water gas producer in place of coke? It can be. Many experiments have been made to this end and many plants built for this purpose. But the losses and difficulties attendant upon the use of soft coal direct in water gas producers have prevented the general introduction of such processes. A continuous process whereby the volatile constituents of a body of coal may be distilled, and simultaneously the resulting coke converted into water gas, producing what would be practically a mixture of bench gas and water gas, has not as yet been evolved.

Producer Gas. Of all the commercial gases producer gas is the easiest and cheapest to make. It is made by simply passing air or air and steam through a body of fuel. The fuel may be soft coal, hard coal, coke or wood. The oxygen of the air unites with the carbon to form carbonic acid and carbonic oxide. In order that the resultant gas may contain as little carbonic acid as possible a comparatively deep bed of fuel is carried and the steam and air are caused to travel through at a moderate rate of speed. If no steam is used the fuel bed will get hotter and hotter, causing the ash to fuse to clinker and give trouble in cleaning out. Steam serves to keep the producer in good working condition, but in addition some of the steam is decomposed, so that the resulting gas will contain some carbonic acid and carbonic

oxide derived from the steam oxygen and some hydrogen derived from the steam. Of course if coke is the fuel used there will be practically no hydrogen in the made gas except that derived from the decomposition of steam. When gasifying fuel in a gas producer and using only air as blast, the temperature becomes excessively high. There is more heat evolved by the burning of carbon to carbonic oxide than the made gases can carry away by their "sensible" heat. Then in order to utilize this excess of heat and also to keep the producer in good working condition steam is admitted with the air blast in such proportions as will accomplish these ends. Decomposition of a portion of the steam absorbs a portion of this excess heat. The hydrogen of this decomposition is directly added to the volume of the gas as free hydrogen. The oxygen so derived will react with carbon to form carbonic oxide and thus increase the volume of gas made. And to the extent that the steam furnishes oxygen, just so much less air-oxygen will be required and the dilution of the gas by air-nitrogen will be correspondingly lessened. When gasifying hard coal or coke more steam can be decomposed than when gasifying soft coal, for the reason that, in the latter case the driving off and breaking up of some of the contained hydrocarbons absorbs some of the excess heat, leaving less to be used for the decomposition of steam than in the case of hard coal or coke, which contain no hydrocarbons to be distilled.

The manufacture of producer gas is a continuous one. Fuel is fed as needed and a continual supply of air and steam is added. If hard coal or coke is the fuel the gas comes off comparatively clean and requires little scrubbing for use in gas engines. But if soft coal is used the gas contains a large amount of tarry vapors and is extremely dirty. By suitable scrubbing it may be cleaned, when it is admirably adapted for use in gas engines. Producer gas is almost universally used in open hearth steel furnaces and regenerative heating furnaces. For such uses no scrubbing is necessary, as the flues through which the gas passes are made very large and accessible for cleaning out or burning out. When the gases reach the furnace where it is consumed the tarry vapors

are more a help than a hindrance. This gas does not burn freely when cold. Consequently either the gas or the air to burn it, or preferably both, should be heated before entering the furnace. This is accomplished by passing the air and gas through chambers filled with brick which have been heated previously by the products of combustion leaving the furnace. A furnace so equipped is known as a regenerative furnace and the chambers as regenerative chambers. It is evident that two sets of such chambers are required, one set being heated by the products of combustion, while the other set are heating the air and gas passing through them. A suitable arrangement of reversing valves is provided whereby the operation of the two sets of chambers may be reversed. The fact that producer gas does not burn readily when cold, together with the fact that it contains about sixty per cent. of incombustible constituents render it unfit for general distribution. Many gas "processes" have been exploited which consist in adding a percentage of oil gas to producer gas. Of course the heating value of the mixture will be enhanced by the amount of heat in the oil gas added. And sufficient oil gas may be mixed with producer gas to make the mixture luminous. But even with such additions the resulting mixture must contain the inert nitrogen derived from the air in the manufacture of the producer gas together with the unavoidable presence of more or less inert carbonic acid. While producer gas varies, according to the fuel used and the condition of the producer, the following may be taken as a typical analysis, using soft coal, with the producer in good condition; composition by volume:

Hydrogen	H_2	10.00%	Combustible, 36.50%
Marsh Gas	CH_4	3.00%	
Olefiant Gas . . .	C_2H_4	.50%	
Carbonic Oxide . .	CO	23.00%	
Carbonic Acid . .	CO_2	5.00%	Incombustible, 63.5%
Oxygen	O_2	.5 %	
Nitrogen	N_2	58.00%	
		100.00	

Using the calorific values given before for the constituent gases the above gas has a calorific value of 144 B. T. U. per cubic foot. It has about one-seventh the heating value of natural gas.

TYPICAL ANALYSES.

	H_2	CH_4	CO	C_2H_4 ILLUMINANTS.	CO_2	N_2	O_2	B.T.U CU FT	O_2 FOR COMBUSTION	AIR FOR COMBUSTION	B.T.U. IN 1 CU.FT. EXPLOSIVE MIXTURE
BENCH-GAS	46.00	40.00	6.00	5.00	50	2.00	5	646	1.21	6.05	91 7
WATER-GAS	48.00	2.00	38.00		6.00	5.50	5	295	.47	2.35	88.0
PROD'R GAS HARD COAL	20.00		25.00		5.00	49.50	.5	144	.225	1.12	68.0
PROD'R. GAS; SOFT COAL	10.00	3.00	23.00	50	5.00	58.00	.5	144	.24	1.20	65.5
PRODUCER GAS; COKE	10.00		29.00		4.50	56.00	5	125	195	98	63.0
CARBURETTED WATER-GAS	40.00	25.00	19.00	8.50	3.00	4.00	5	575	1.05	5.25	92.0
COKE OVEN GAS	50.00	36.00	6.00	4.00	1.50	2.00	.5	603	112	5.60	91.0
BLAST FURNACE GAS	1.00		27.50		11.50	60.00		91	143	.72	53.0
NATURAL GAS; PITTSBURG.	3.00	92.00		3.00		2.00		978	1.945	9.73	91 0
OIL-GAS	32.00	48.00		16.50		3.00	5	846	1.615	8.07	93.0

CONSTITUENTS OF COMMERCIAL GASES.

	CHARACTERISTICS	MOLECULAR SYMBOL.	MOLECULAR WEIGHT	B.T.U PER CU.FT	B.T.U. IN 1000 CU.FT FROM 68°-68°F.	CU.FT. O_2 TO BURN 1 CU.FT.	PRODUCTS OF COMBUSTION.
HYDROGEN	BLUE FLAME: VERY "SNAPPY"	H_2	2	320	320,900	.5	H_2O
OXYGEN	SUPPORTER OF COMBUSTION	O_2	32				
NITROGEN	INERT	N_2	28				
CARBONIC ACID	INERT, BURNT CARBON	CO_2	44				
CARBONIC OXIDE.	VERY POISONOUS; PARTIALLY BURNT C. BLUE FLAME	CO	28	320	320,580	.5	CO_2
MARSH GAS	SLIGHTLY LUMINOUS. ODERLESS	CH_4	16	1000	993,550	2	CO_2 & $2H_2O$
OLEFIANT GAS	LUMINOUS	C_2H_4	28	1600	1,560,100	3	$2CO_2$ & $2H_2O$
ACETYLENE	VERY LUMINOUS	C_2H_2	26			2.5	$2CO_2$ & H_2O

Inasmuch as carbonic oxide (CO) burns to carbonic acid (CO_2) it is evident that the presence of carbonic acid in the analysis indicates that the producer has been operated in such a manner that some of the carbonic oxide has been burned in the producer. In practice it is not possible to eliminate the carbonic acid altogether, but if it goes over five per cent. it indicates that the gas maker is not exercising the diligence that he should in watching the condition of his producer.

A typical analysis of producer gas from hard coal is as follows:

Hydrogen	H_2	20.00%
Carbonic Oxide	CO	25.00%
Carbonic Acid	CO_2	5.00%
Oxygen	O_2	.5 %
Nitrogen	N_2	49.50%
		100.00

The above gas has a calorific value of 144 B. T. U. per cubic foot. But it is noticeably different from the analysis of gas derived from soft coal in the higher percentage of hydrogen and the entire absence of marsh gas. The higher percentage of hydrogen is due to the decomposition of steam, as already explained.

To make gas of the above analysis demands that the producer be handled with intelligence and kept in the best working condition.

Oil Gas. When crude oil, refined oil, tar, naptha, "tar oil" or any of the heavy, liquid hydrocarbons are subjected to heat they are broken up to a greater or less extent and gases and vapors are evolved. The gases thus evolved are hydrogen, marsh gas and olefiant gas. The vapors are not "fixed gases," but will condense to liquid form at lower temperature. But a gas will serve as a "carrier" for a certain amount of a vapor. Just as air will carry a certain amount of water vapor, depending upon its temperature, so will any gas or mixtures of gases carry a certain amount of the vapors of hydrocarbons. Thus when gasolene is used in gas engines it is not converted into a gas before entering the cylinder; it is only vaporized and the air serves as the carrier of the vapor. Gasolene vaporizes at ordinary atmospheric temperatures and requires no heating to induce it to give off its

vapors. Ordinary kerosene vaporizes at about 150° Fahrenheit, and if heated to this temperature it can be used in gas engines the same as gasolene, and air can be used as the carrier to convey the vapor into the cylinder of the engine. The temperature at which an oil begins to evolve an inflammable vapor is called its "flash point." Usually this vapor can be broken up into a lower hydrocarbon by the application of more heat at higher temperature. Such breaking up will be generally accompanied by the deposition of carbon. The most general application of oil gas is for carburetting water gas to change the blue flame to a luminous one. In round numbers a barrel of crude oil contains 7,000,000 B. T. U. A ton of good soft coal contains 28,000,000 B. T. U. So that four barrels of oil are equivalent in heating effect to one ton of coal. But it is possible to burn oil more efficiently than coal is usually burned. This is partially due to the unavoidable loss of a portion of the coal in the ash and clinker. Consequently it has been found in practice that about three and one half barrels of crude oil are equal to one ton of coal, when both are burned under favorable conditions, attainable in good practice. Various oil gas processess have been exploited and all sorts of claims have been made as to the amount of gas and its calorific value that can be derived from one barrel of oil. But in considering such processes it is well to keep in mind that a barrel of oil contains a certain number of thermal units. To gasify the oil will require a certain number of thermal units. If there were no loss of heat in the gasification process, which is a condition unattainable in practice, then the gas made from the barrel of oil would contain just the thermal units contained in the oil originally, plus that amount required to gasify the oil. In other words the only thermal gain that can be made by gasifying oil and burning it, over burning it direct, is that due to the more complete combustion that can be obtained when the oil has been first gasified or vaporized. As a question of fact crude oil can be burned with properly designed burners which insure a complete mixture of air and oil, with as high an efficiency as can be obtained by first vaporizing it and then burning it. No typical analysis of oil gas can be given, for the composition depends upon the oil from which the gas is derived and

the temperature to which the oil has been subjected, but the following may be taken as typical of oil gas made from Pennsylvania crude oil; analysis by volume:

Hydrogen	H_2	32.0%
Marsh Gas	CH_4	48. %
Illuminants	C_2H_4	16.5%
Nitrogen	N_2	3.0%
Oxygen	O_2	.5%
		100.0

The above gas is noticeably different from Bench gas in the high percentage of illuminants.

Coke Oven Gas. Most of the coke used for metallurgical purposes is made in "bee-hive" ovens and no attempt is made to save the volatile constituents of the coal. The product desired is coke not gas. But of recent years there has been introduced the "by-products coke oven," in the operation of which the gases, tar and ammonia evolved by distilling the coal in closed retorts or ovens are saved as in the bench gas process. A considerable portion of the gases evolved are used in heating the ovens. The remainder is almost identical in its composition with bench gas. Generally it is higher in hydrogen and lower in "illumnants" than bench gas, because the ovens are operated to produce a hard coke suitable for metallurgical purposes and the illuminating power of the gas is a secondary consideration. For use in gas engines it may be considered as bench gas. When it leaves the ovens it is very dirty and before it can be distributed or used in engines must be thoroughly scrubbed. Inasmuch as the scrubbing process recovers valuable by-products in the form of ammonia and tar it more than pays for itself.

Blast Furnace Gas. The gas evolved from a blast furnace during the operation of smelting iron ore to pig iron is very similar to a low grade or lean producer gas. Notwithstanding its very low calorific value, rarely over 100 B. T. U. per cubic foot, it gives excellent results when used in gas engines. Bell, in Iron and Steel, gives the following as an average analysis:

Hydrogen	H_2	.70%	Combustible, 27.4%
Carbonic Oxide . . .	CO	26.70%	
Carbonic Acid . . .	CO_2	11.70%	Incombustible, 72.60%
Nitrogen	N_2	60.90%	
		100.00	

The above gas has a calorific value of 88 B. T. U. per cubic foot. Upon leaving the furnace the gas contains considerable fine dust, particles of the furnace charge, which may be readily removed by suitable scrubbing apparatus. As coke is the fuel in a blast furnace, almost invariably, the gas contains no tar or heavy vapors. There can be no doubt that the next few years will show a great development of the use of this gas for purposes of power.

Natural Gas. Natural gas varies considerably in its composition. But its chief constituent is always marsh gas. This may vary from 85 to 95 per cent of the total volume. Some times considerable hydrogen is present, indicating that some marsh gas has been broken up by heat. Also it not infrequently carries a small percentage of oil vapors. Its calorific value is usually about 1,000 B. T. U. per cubic foot. It works admirably in gas engines. Particular care must always be taken to insure sufficient air for combustion. About fourteen cubic feet of air should be supplied for each cubic foot of gas. When an insufficient supply of air is given there will result a deposit of carbon and the formation of a small percentage of acetylene, $C_2 H_2$, giving a pungent odor to the products of combustion.

THE UTILIZATION OF BLAST FURNACE GASES FOR POWER PURPOSES.

The development of the gas engine in large sizes has drawn attention to the economical and other advantages incident to their employment to produce blast for blast furnaces by direct use in them of the furnace gas commonly consumed to produce steam for blast power. The quantity of gas required by the gas engine is much less than that for steam raising where power requirements are equal. The excess of gas production, necessarily incident to blast furnace operation, even where steam power is employed, is practically wasted. The larger excess, resulting from the substitution of gas engines, can be utilized by their further application for power purposes additional to that required for the operation of the furnace.

It has already been demonstrated in both this country and Europe that this gas works well in gas engines. There is no trouble in cleaning it and not withstanding the fact of its low calo-

rific value, never over 100 B. T. U. per cubic foot, it burns readily in the cylinder when compressed and mixed with a suitable proportion of air.

The purpose of this paper is to set forth the possibilities of a blast furnace as a source of power and to show the amount of power available over and above that required to operate the furnace and heat the blast. The data for the calculations are derived from various sources and rather than confine himself to the operation of one particular furnace the writer has averaged results and presents typical data of good modern practice.

DATA FOR CALCULATION.

Coke. Good, hard coke, 85 per cent. fixed carbon.

Limestone. 42 per cent. CO_2, containing 115 lbs. carbon to 1,000 lbs.

Pig Iron. Analysis Fe 94.00 C 3.75 Si 2.00 S, P, etc., .25.

The above pig iron is of good average quality, and the coke and limestone are such as ordinarily used.

Furnace Gases. Analysis by volume with weights calculated upon the basis of 1,000 cubic feet.

CO_2	11.7	in 1,000 cu. ft.	13.572 lbs.,	containing	3.70	lbs. Carbon.
CO	27.5	" "	20.268	"	8.685	"
H_2	.8	" "	.042	"		
N_2	60.00	" "	44.257	"		
	100.00		78.139		12.385	lbs. Carbon.

The above gas is almost identical with that given by Bell in "Iron and Steel," and by Gayley in "Transactions Am. Inst. M. E." Vol. XIX.

Weights are calculated at a temperature of 62° F. and it will be noted that 1,000 cubic feet weigh 78.139 lbs. and contain 12.335 lbs. carbon.

Furnace Charge. To produce one ton (2,000 lbs.) pig iron:

Ore	3400 lbs.
Coke	2000 lbs.
Limestone	1000 lbs.

The coke consumption is low, but not as low as has been

obtained in exceptionally good practice. It is evident that the amount of gas produced is a function of the amount of coke charged; and the amount of power available is a function of the amount of gas produced; therefore, in taking a low figure for coke consumption we are on the safe side in an estimate of available power.

All the carbon charged into the furnace must appear in the pig iron produced and in the furnace gases evolved. There is no other place for it to go. The amount that would accumulate in the dust catcher or be blown out as free carbon in the gases is so small compared to the amount charged as to be negligible.

The furnace charge contained in 2000 lbs. Coke.....	1700 lbs. Carbon.
The furnace charge contained in 1000 lbs. Limestone.. ..	115 lbs. Carbon.
	1815 lbs. Carbon.

The 2,000 lbs. pig iron produced from the above charge contained 2,000x0.0375=75 lbs.

Therefore for each ton of pig iron produced there went to the gases 1,815—75=1,740 lbs. carbon contained in the gases for each ton of iron made. But from the weights of the gases, given above, 1,000 cubic feet of gases contain 12.335 lbs. carbon. Therefore there will be evolved for each ton of iron 1,740/12.335=141,000 cubic feet.

The analysis of the above gas shows 60.00% nitrogen. This is derived from the air which is by volume 79.00% nitrogen. It follows that the amount of air required to produce this gas must be in proportion to 60 to 79. Or 60/79=0.76. That is to say for each 1,000 cubic feet of gas made 760 cubic feet of air were supplied. But we saw that one ton of iron evolved 141,000 cubic feet of gas. Therefore there must have been supplied for each ton of iron 141,000x0.76=107,160 feet air.

This figure checks very closely with the measurements of air furnished as based on speed of blowing engines and cylinder displacement. Of course more air than this can be supplied and more coke consumed, with a consequent increased volume of gas produced.

It has now been shown that in good practice one ton of pig iron will evolve 141,000 cubic feet of gas. The analysis of the

gas shows it to be 28.3% combustible and to have a heating value of 90 B. T. U. per cubic foot. And 141,000x90=12,690,000 B. T. U.

The 2,000 lbs. coke from which this heat was derived contained 24,650,000 B. T. U. Hence we have, for the endothermic reaction of the reduction of the ore, sensible heat of slag and metal, radiation, etc., the difference between these two figures, 24,650,000—12,690,000=11,960,000—which is to say that about one-half the heat potential contained in the coke charged into the furnace is contained in the gas leaving the furnace. Furthermore, this heat potential is in the best possible condition for conversion into power. It is in the shape of a clean, combustible gas admirably adapted for use in gas engines.

But all the gas evolved is not available for use as power. Some of it must be used to heat the blast. We have seen that 107,160 cubic feet of air are required to produce one ton of pig iron. One thousand cubic feet of air at 62° F. weigh 76 pounds. Or the weight of air per ton of pig iron is 8,144 pounds. Taking the specific heat of air at 0.25, which is sufficiently high to account for the contained moisture, we have, to heat the air through 1,000° F., 8,144x1,000x0.25=2,036,000 B. T. U.

But the stoves are of low efficiency and to be on the safe side and allow for losses of radiation and imperfect combustion, we will assume an efficiency of but 50 per cent. This will double the above requirement and give for heating the blast 4,072,000 B. T. U. With well designed stoves of sufficient capacity this should be ample. In fact the writer has been informed that stoves have been operated with an efficiency of 80 per cent.

For purposes other than heating the blast there remains, therefore, from one ton of iron produced 12,690,000—4,072,000=8,618,000 B. T. U.

Our original ton of coke contained 24,650,000 B. T. U. After heating the blast we have in the form of gas 8,618,000 B. T. U. remaining, or 35.0 per cent. of the total heat value of the coke.

Used in gas engines, how much power will this heat produce?

A very conservative figure for the B. T. U. per B. H.P. hour in gas engines is 12,400 B. T. U. Much lower results have been

obtained. Dividing the heat available for power, which we find to be 8,618,000 B. T. U., by that required to produce a H.P. hour, 12,400, we have 700 brake horse power hours as the amount available in the gas evolved from the production of one ton of pig iron.

If the furnace is producing ten tons per hour or 240 tons per day there is gas evolved capable of operating 700x10=7,000 horse power of engines over and above that required to heat the blast.

If the furnace has a capacity of fifteen tons per hour or 360 tons per day, a not unusual size, the surplus gas used in gas engines would produce 700x15=10,500 B. H.P. per hour.

At first blush this statement seems absurd and preposterous. But there is nothing absurd or preposterous about it. Remember that the gas available for power contains 35.0 per cent. of the heat of the coke charged and that it is in the form of gas. And also that the heat in the original ton of coke, if in the form of gas, would produce nearly two thousand horse power. And, as a question of fact, with a properly designed gas producer one ton of coke will produce 1,500 HP. per hour.

But the blowing engines and other machinery about the blast furnace must be driven with a portion of this available power.

How much power is required to produce one ton of pig iron?

Our figure on air supplied for one ton of iron produced was 107,160 cubic feet. If we consider a furnace having a capacity of 360 tons per day we would require engines capable of delivering 107,160x360/24x60=26,790 cubic feet of air per minute.

To check the above figure attention is called to Mr. Gayley's statement that Edgar Thomson furnace F produced 385 tons per day with an air supply of 25,000 cubic feet per minute. This is, however, exceptionally good practice.

To furnish 26,790 cubic feet of air per minute at ten pounds pressure and allowing ten per cent. for friction load, there would be required 1,200 B. H.P. In addition there are other pieces of machinery to be driven for which provision must be made. Place the figure then at 1,500 B. H.P. as the power required to operate a furnace of 360 tons capacity. But we had an available power on this size of furnace, as seen above, of 10,695 B. H.P. Therefore

we have a surplus over and above all the requirements of the furnace of 10,500—1,500=9,000 B. H.P. In all the calculations we have given the other side the benefit of the doubt, and we have, in the gas necessarily produced by a 360-ton furnace, an available horse power beyond all the demands of the furnace of 9,000 B. H.P. *per hour*. Dividing this figure by the tonnage per hour, or fifteen, and we have as the *surplus* power-producing capacity of a modern blast furnace using gas engines six hundred horse power per hour per ton of iron produced. Or per ton of iron produced *per day* we have a surplus of power of twenty-five horse power *per hour*. Would it not be well for blast furnace managers to consider the furnace as a gas producer for power purposes, producing pig iron as a by-product?

THE PRESIDENT—Gentlemen, I was informed by the chairman of the Program Committee that we were going to have a paper to-night that would be a good one, and I think you will all agree with me that that expectation has been realized. Aside from the technical features of the paper there are several things about it that were very striking—that were, in fact, models of what a good paper should be. Mr. Gow started in with his alphabet, as he called it, in which he made his preliminary steps so clear, and followed the one after the other in logical sequence, so that every man, by the time we heard that alphabet, fully comprehended that much of the subject. He then went on with special applications which we were prepared to understand in view of the preface. In other words, aside from its technical value, it is one of the best model papers I think I have ever had the pleasure of listening to in this Society. It is furthermore written in good English, and this is a feature which I think every author of a paper appreciates. It is one that compels attention from the reader or hearer of the paper, and it is one that reflects credit upon the author of the paper. The subject itself, especially the part that tells of the treatment of blast furnace gases, only confirms my own opinion that we live in the most favored part of the globe, in spite of its dirt.

We have natural gas here. Here is unlimited power from these blast furnaces which we have in Allegheny County, and which we might utilize. After a while, perhaps we will do our

cooking and heating and everything for almost nothing. We will have more than we can possibly use. Mr. Hall, if you will remember, at our banquet, brought out the tendency in Germany towards saving in the fuel end of the plant rather than the labor end. This we know is true. The blast furnace gas has been utilized to a greater extent in Germany than it has sbeen here. At the Lackawanna plant they are putting in a great many gas engines. It shows the tendency of the times. A paper of this kind, which is, if anything, a little in advance of present practice, gives engineers food for thought. We all know that the producer gas is used now, and this paper outlines the greater uses to which it will bc put in the future.

The paper is now open for discussion.

A MEMBER—Mr. President, I would like to ask a question in regard to this paper, that is, in applying gas to a single blast furnace, how much other power would be necessary to have to start the furnace into blast?

A MEMBER—I would like to ask one question, and that is in the gas engines used for natural gas consumption, how would they compare in size with engines for the utilization of blast furnace gas? Does the low heat unit require a larger engine for the utilization of it?

MR. FLINT—It does require a somewhat larger engine than the natural gas, on account of the large percentage of nitrogen. I have a short paper here in which I have taken up that point.

PROF. KINTNER—Mr. President, Mr. Flint has proved a good substitute for Mr. Gow, and in addition, Mr. Flint had promised a discussion of the paper. I am sure we would be much interested if he would enter into the discussion of Mr. Gow's paper.

MR. FLINT—I did not plan to discuss Mr. Gow's paper, but I did write out a short paper on a kindred subject which, with your permission, I will read.

POWER AND ECONOMY OF THE GAS ENGINE AS INFLUENCED BY THE FUEL.

BY WM. P. FLINT.

The Gas Engine is a heat motor in which the products of combustion of a mixture of gas (or oil vapor) and air, take the place of steam.

Since all our principal fuels are combinations and mixtures of carbon and hydrogen, nitrogen and oxygen, and are burned by the addition of air, we find that the products of combustion of all of them consist of a mixture of nitrogen, carbonic acid and water vapor. The proportion of these three ingredients varies somewhat, but as nitrogen is always predominant we may, for general reasoning, safely consider that the burned gases have about the same composition in all cases. These burned gases constitute the working fluid and are heated by the combustion of the explosive mixture from which they are formed.

The degree of this heating depends on the amount of chemically latent heat which the explosive mixture contains. Those products of combustion which consist of water vapor, cannot be cooled in a gas engine to the point where they give up the latent heat of vaporization of steam, hence for comparison of different gas engine fuels it is common to distinguish between the total and the effective heat value of the gas. The latter is calculated from the former by deducting about 1000 BTU per pound of water vapor formed.

It is interesting to note that so long as the original fuel is not adulterated by the admixture of an inert constituent such as nitrogen, there will be an almost constant number of heat units available per cubic foot of explosive mixture.

At first sight this would not be expected, for some gases will give several times as many heat units per cubic foot as others. Upon looking closer, however, we find that those gases which

give the greatest heat value are the ones which require the greatest amount of air to burn them and that when we divide the effective BTU per cubic foot by 1 cu. ft. gas + the number of cu. ft. air it requires, we have in all cases about the same number of BTU per cubic foot of mixture.

The exceptional case referred to, namely, where there is an excess of nitrogen in the original gas, merely proves the rule for this notrogen dilutes the resulting mixture, making it weaker.

Good Producer Gas, for instance, has about 55% of nitrogen and other inert ingredients, and as a result its heat value per cubic foot of explosive mixture is about 80% of that for natural or illuminating gas.

We find in practice that the maximum I.H.P. of an engine will be very nearly proportional to this effective BTU per cubic foot mixture. As the mechanical efficiency of the gas engine is in the neighborhood of 85%, this means that if a natural gas engine be used on producer gas it will give about 75% of its rating. As, however, the less powerful explosive mixture obtained with producer gas gives less maximum pressure, it is possible to bring up the power of an engine to its natural gas standard by enlarging the cylinder diameter without making corresponding increases in shaft and other dimensions.

Similarly with Blast Furnace Gas, which is more diluted even than Producer Gas, the cylinder diameters may be enlarged out of the natural gas proportion to the other dimensions of the engine.

It is found that while the power of an engine varies somewhat with the fuel used, that thermal efficiency and hence the BTU per B.H.P. is nearly constant. Twelve thousand effective BTU, whether from 12 feet of natural gas or from 85 feet of producer gas, will give one B.H.P. at full load in a suitably designed engine.

All the commercial fuel gases are really mixtures of a number of distinct gases. Natural gas, which is the most homogeneous of all, is chiefly marsh gas, or $C.H^4$, but usually contains a small percentage of some of the higher hydrocarbons (usually classed as illuminants when occurring in artificial gas). It is cer-

tainly an ideal fuel and where it is cheap and abundant there is little occasion to consider any other, unless it be blast furnace gas.

From 10 to 12 cubic feet of natural gas are required per B.H.P. hour.

Producer gas is a mixture of carbon monoxide (C O) and hydrogen (H), with a large amount of nitrogen and other inert ingredients. It is a first-class fuel for gas engines and is destined to play an important part in the supply of power throughout the world. While not so powerful as natural gas, it has the great advantage of being available wherever coal or wood for making it can be obtained. In fact, its use is most advantageous where fuel is most expensive, for then the great economy of the producer and gas engine combination over the boiler and steam engine combination means most in dollars and cents. A producer gas plant will give a brake of H. P. on 1¼lbs. or less of good coal

BLAST FURNACE GAS.

Blast Furnace Gas when properly cooled and cleaned from dust, and when drawn from a number of furnaces so that the supply may never be shut off, is an ideal gas engine fuel, and the day is coming when no blast furnace can afford to throw away its gas or to waste it by inefficient use under steam boilers. This gas is now extensively used in Europe for power purposes, and it is found that there is a large surplus of power available for electric transmission over and above that required for the gas engine driven blowing engine.

ILLUMINATING GAS.

This is usually a mixture of hydrogen, carbon monoxide, marsh gas and some of the higher hydrocarbons, which last are often styled illuminants, since their exact composition is difficult to determine.

It is more troublesome than natural gas to use in a gas engine, since the hydrogen it contains is rather touchy and sometimes ignites sooner than desired. Except for small engines and for the owners of gas works, it is too expensive a fuel for power

purposes. A good many large engines using this fuel have been installed at gas works, where it is figured that they pay, owing to the absence of pipeage charges and to the economy of gas production following an increased rate of production.

Mr. Scott—At the meeting of the Electro-Chemical Society, in New York last week, the president of the society, Prof. Richards, of Lehigh University, gave a most excellent address, the presidential address. It will probably appear in the technical papers, and I advise you to be on the lookout for it, and to read it. It takes up the electro-chemical industry at present, and has excellent ideas. What he says may well be applied to other industries. In the address he looks forward to the future, when there is a utilization of the gas from blast furnaces, and he gave figures which correspond very well with the figures given this evening,—that the power available from blast furnaces is 10,000 H. P. I have made some little endeavor with the facilities available this evening, to ascertain what this really means, by determining the number of blast furnaces. There seems to be some variation as to the opinions of my informants as to the number. It is varied all the way from 39 to 300. My informants are not quite sure whether the whole earth, or this country, or just Allegheny county is included.

They finally determined that in Allegheny county alone there are 39 or 40 blast furnaces, meaning 400,000 H. P. of fuel in this one county, which is all heated up hot, ready for the gas engines, which is going to waste. The recent developments in electrical transmission of power removes the necessity of placing the engine exactly where the power is needed, as this power can be made available within a reasonable radius, even within two hundred miles. The development of the power at Niagara Falls, which has brought to the city new industries requiring large quantities of cheap power, have been built up from the Niagara Falls Power Co. which has, up until the last few months, had available less than 50,000 H. P. The industries which had their beginning in Allegheny county for the production of aluminum, carborundum, and other industries for the production of calcine and carbide, bleaching powders, and a number of other things, the running

of the street railways from Niagara Falls to Buffalo, the lighting of Buffalo, and thousands of manufacturing industries, and the building of new industries, with the whole transformation of that section of the country, have been made by a power development of only 10% of the power that is going to waste here in Allegheny county. A remark made to me not long ago by one of our ex-presidents has impressed me. It was to this effect, that the developments in the Pittsburg region, during the past ten to twelve years, have not been the highest type of engineering work. They have been rather to get out the products, to get them out quickly, and on a large scale. The practical engineer will come in a little later, when the times of prosperity may wane, and it will then be up to the engineer to increase the efficiency of the production at times when severer competition comes up between this country and other countries, and in the days of hard times. It is a case of tonnage, and not a case of dollars. It is up to the engineer to produce tons and not produce the cost so much. There is one question which I may have possibly answered myself, but I do not think I have given the whole answer. We have heard from our gas engine expert some very astonishing figures as to what can be done, but I do not think we have had an answer to why it has not been done to a greater extent. Are there technical difficulties to overcome, or is it simply an elegant thing which, after all, is not worth going after?

MR. SWENSSON—What is the largest size of a gas engine that can be produced?

MR. FLINT—I think 1,000 H. P. engines can be produced now. A few years ago not many of that size were in use.

MR. SWENSSON—Is there any one of that size in successful operation? What is the largest in the United States?

MR. FLINT—I know we have had several 500 H. P. engines running for three, four, or five years.

MR. SWENSSON—You know one of the Duquesne furnaces requires about 5,000 H. P. When we can build gas engines as well as steam engines, perhaps they will be more successful.

MR. FLINT—What size blowing engine do you use?

MR. SWENSSON—Perhaps about 2,000 or 3,000 H. P.

THE PRESIDENT—The Lackawanna Steel Co. use 700.

Mr. Crooker—Last winter a friend of mine looked into the steel works over in Germany, and visited 25 furnaces at Luxemberg and different place. He was very enthusiastic. In the blowing furnaces in Germany, they found that only one-tenth of the gas was required to blow their furnaces. One thing I think there will have to be different arangements of our American works if we come to use gas engines for blowing furnaces. We will have to quit the American style of works, and concentrate and make a different style of works from what we have.

Another thing which has not been brought out: last week I had a talk with a friend who is back from Europe. He said that since getting the large engine to work successfully, that that was only part of the story, that there was an enormous room required for the scrubbers for the gas. It will be accomplished, but will require money in addition to the plant itself.

Whether that would be as much as required for boilers, I am not prepared to say, but there is a cloud there in the matter. That is probably one of the reasons they are not used more.

Mr. Diescher—Talk about the waste of fuel in coke ovens. About two years ago I had occasion to inquire into this matter, and I learned that the gas bi-products, ammonia, and tar, together amount to more in money than they get for the coke. We are used to waste. We do not mind a little smoke. We do not feel that business is good unless there is lots of it, but if anyone will come to find out what it means, he will find that there are $25,000,000 per year getting away in smoke.

Mr. H. J. Lewis—Looking into the future, I think I am laying myself liable to the accusation of being a trust-builder, because the making of an ideal steel plant seems to involve absolute consolidation of all operations as closely as possible to each other. First, making the coke in the bi-product ovens and saving as much gas there as possible of that rich gas to be used where rich gas is needed, again saving and utilizing the gas from the blast furnace shown by the paper, and if Mr. Scott and his colleagues can design a five, six, seven, eight thousand H. P. motor which won't buck, and which will pull a mill clear through, I believe we won't need to use very much auxiliary fuel outside of coal, which is taken to the blast furnace for the entire finishing

of the material in the mill yard, but we may have to wait until our nine-foot coal is worked out before it would be commercially possible, because our friends, the business men, figure these things in dollars and cents, and as long as coal itself is so cheap, they are not liable to trouble themselves about a lot of expensive appliances.

A MEMBER—There is one question I would like to ask Mr. Flint in regard to the operation of gas engines with producer gas. Is there any difficulty arises from heavy hydro-carbon distilled out of the coal being deposited in the valves of the engine?

MR. FLINT—It is necessary to scrub it. You have to remove that tar, because otherwise it will deposit in the valves, and stick the engine up so that it would not operate satisfactorily. That has been one of the drawbacks in the operation of an engine with soft coal producer gas. There is no tar to speak of in hard coal producer gas.

THE PRESIDENT—We have had quite an interesting discussion, and we have an inkling of the reason why some hundreds of thousands of H. P. are being wasted every day, and we find that perhaps men who have dollars are a little right in being slow about taking this up.

PROF. KINTNER—Before the motion to adjourn, I move that the Society extend a vote of thinks to Mr. Flint for reading Mr. Gow's paper, and also for his own paper.

MR. CROOKER—I would add to that, and thank Mr. Gow also. Motion carried.

On motion, the Society adjourned at 10 o'clock and 45 minutes.

CHARLES W. RIDINGER,
Secretary.

COAL HANDLING MACHINERY AND ITS APPLICATION TO STEAM POWER PLANTS.

BY T. F. WEBSTER.

In the year 1902 there were over 335,000,000 tons of coal mined in the United States. All of it was necessarily handled two or more times, at a cost for each handling of from two to twenty-five cents per ton. Assuming the average cost for each of these two handlings to be ten cents per ton, the total expenditure for this purpose amounted to about $67,000,000 for the year; a conservative estimate, inasmuch as the most of it is still handled by primitive methods. With such an amount in view, it is not difficult to account for the attention given to the subject of the handling of coal by mechanical means. On account of the large quantity consumed, the problem has come to be of more common interest than that of handling any other material, and it is of special interest to all who have to do with not only the mining of it but also the shipping, storing, selling and consuming.

On account of the many different conditions under which it is handled, the methods are almost as varied as the results desired, and they have reached such a high stage of development that machinery for each purpose comprises a separate and distinct class, such as machinery for mines and coking plants, storage of coal in large quantities, say from 20,000 to 400,000 tons; hoisting, coal washeries, retailing plants, shipping piers, car dumpers and power plants. Each class is very interesting in itself, and those not familiar with what has been done along this line, will be surprised at the results that have been obtained. In the storage of coal in large quantities, say from 20,000 to 400,000 tons, hoisting, screening and reloading coal for a little less than five cents per ton, on an average, throughout the year, including all labor, repairs and office expenses. Vessel loading machines are built with a capacity of from 600 to 1,000 tons per hour. At 600 per hour, the cost of labor is less than one-quarter of a cent per ton.

In this paper, however, I wish to call your attention particularly to the mechanical handling of coal in steam power plants, touching upon the other classes only in their connection with such plants.

The common purpose of all manufacturers is to turn out their products at the least possible cost. The fixed expense account of a plant depends upon its mechanical equipment and therefore everything entering into it should have the careful consideration of the engineer. The cost of power is a most important factor and depends directly upon the cost of fuel, the cost of fuel in turn depending upon the purchase price and the method of handling.

The methods of handling coal in power plants are also varied, and the selection of the proper machinery to adopt for the purpose depends upon:

(1) The size of the plant;

(2) The amount of reserve storage necessary;

(3) The size of coal to be handled;

(4) The rate at which it must be handled; and

(5) Whether the delivery to the plant is to be by rail or water.

Obviously it is always an advantage to locate the plant as close to the delivery point as possible. That is, in case of supply by rail, the dumping point should be near to the side or end of the boiler house, and if brought by water, as near to the water's edge as it is possible to construct it, so that it can be discharged directly into the distributing conveyor, avoiding the necessity of intermediate carrying machinery. If the location does not permit of this, it is carried from the delivery point to the power plant either by a system of cars or a conveyor.

The hoist should be arranged to elevate the coal high enough to transfer it to a distributing conveyor without an additional elevator, unless the delivery point is located so far away that the extra cost of such an arrangement would be greater than that of an elevator at the building. It may be found possible, in the case of a small power house, to arrange the hoisting machinery in such a way that it will distribute the coal economically in addition to hoisting it.

The machinery in the boiler room for distribution to the boilers, and the amount of expenditure for it, depends upon the size of the plant and convenience desired. However, no plant is too small for the consideration of the most economical plant to adopt, and the first question that arises is, whether an expenditure for mechanical means is justified or not. As there are rarely two power houses that are subject to the same local conditions, it will be recognized that it is very difficult to lay down a fixed rule regarding this point. There is no question as to there being a great saving by the use of it in the larger power plants, but as it is more expensive per horse power to install in the smaller sizes, and as some are so small and convenient that one man can more than take care of the boilers and firing, there is a point where it ceases to be an economy, although the question of convenience or space may still make it desirable.

In a recent report made to the Steam Users' Association by one of its members, the author of it said that he had found from the reports of four hundred members of the association, that under average conditions one man can run an engine and fire up to ten tons of coal per week, and with the aid of an engineer and night man, thirty-five tons per week, or a 200 horse power plant. Two men, with the aid of an engineer and one night man, can fire up to eighty tons per week, or a 450 horse-power plant, assuming five pounds of coal is required for each horse power per hour.

He also reported that the average cost per ton for about 600 boilers investigated, was 48 cents, the maximum 71 cents, and the minimum 26 cents, and that when coal has to be moved by wheelbarrow, 1.6 cents per ton per yard up to distances of five yards, and about one cent per ton per yard for each additional one.

I find that under the most favorable conditions, or when the coal is dumped directly in front of the boilers and requiring but one shoveling to the furnace, one man can attend to the boiler, coal and ashes for a four hundred horse power plant. When coal is discharged alongside the boiler house, and has to be shoveled twice, it requires one fireman with a helper for each battery of five hundred horse power. Under the most favorable

conditions of this kind that I have ever seen, a fireman and helper were required for each unit of seven hundred horse power. This, however, is unusual. Assuming the fireman's wages per day to be $2.00, and the helper's $1.90, the cost per ton for handling the coal for each battery of five hundred horse-power, equaled 26 cents per ton, and 19 cents for the 700 horse power unit.

Under the same conditions, when machinery is employed, the labor necessary for transferring the coal from the cars to the stoker is as low in many cases as two cents per ton.

The relative cost of handling by hand and by machinery may be illustrated by taking a few examples of plants in which the cost of power has been noted both before and after the machinery has been installed. One plant that comes to my notice is one of 4,000 horse power, consisting of eight batteries of 500 horse power each. Before machinery was installed, the coal was discharged from a trestle alongside of the building, requiring sixteen men to stoke and sixteen passers on each turn. At the above rates per day, the cost of labor amounted to $18,720 per year, when the plant was running twenty-four hours a day. Machinery and mechanical stokers were installed at a cost of about $26,000, including a 500-ton overhead storage bunker. With the aid of machinery, three men were required on each turn for firing, and two on the day turn for the machine. With the wages of the men at $2.00 per day, interest on the investment at six per cent., and depreciation at five per cent., the total expense that could be charged up equaled $7,660 per year, making a difference of $11,160, or about 45 per cent. on the investment. To those not familiar with the results usually obtained, this earning capacity may seem very high, and it does run much lower in smaller installations and in those where conditions make the cost of equipment extraordinarily high. A power house in this city, containing four 500 horse power units, in which coal had to be wheeled about fifty feet, but dumped directly into the stokers, was recently equipped with coal and ashes handling machinery at a cost of about $14,000, including coal and ashes bunkers, taking the place of fourteen coal and ashes wheelers on each turn. The saving per year by this change, after all charges had been made against the machinery, amounted to seventy-nine per cent. on the investment.

Other cases might be cited in which even one hundred per cent. has been realized on the investment, but such opportunities are not open to every manufacturer. It is, however, a very common thing to effect a saving in labor amounting to from 20 to 40 per cent. per year on the investment.

As stated before, the conditions are so variable that a general rule for determining the actual amount that can be gained by the installation of machinery cannot be made.

The next point to be determined is the amount of reserve storage necessary, and its location. This amount is usually determined by the result of an enforced shut-down and the liability of it. For railway power stations, lighting and pumping plants and public institutions, a large storage capacity is required, particularly when located in such a way that the supply is likely to be interrupted. In the largest power houses it varies from one-half to three-quarters of a ton per horse power, a sufficient amount for an eight to twelve days' run, or even more, if the plant is not running full. A supply as large as this may not always be required, yet even in this locality it is not free from possible interruptions either at the mines or in transit.

There are three general methods for taking care of this reserve supply, which may very properly be termed "Emergency Storage":

(1) An overhead bunker large enough to contain the entire amount necessary;

(2) An outside storage alone;

(3) An outside storage, together with a small overhead supply for immediate use.

Overhead bunkers are more common than either of the other two methods. They vary in size and are built to contain even as large an amount as 10,000 tons. In industrial plants they are generally made in sizes of from one to five tons per running foot of the length of the boiler house. They are fitted with spouts about 12" in diameter, for directing coal to either the floor in front of the boilers, or to mechanical stokers. The larger sizes are usually constructed of a combination of steel and concrete, while the smaller ones are entirely of steel. This is on account of the

extra cost per ton of capacity of small sizes of concrete bunkers. Local conditions must again determine the dividing line between the two methods of construction.

Judging from my knowledge of the conditions of several steel hoppers of moderate sizes which have been in use for about ten years, the depreciation amounts to less than five per cent. of the first cost. This may seem low, but from data at hand, it seems to be in fact even lower. If designed properly, the side and bottom plates are the only parts subjected to corrosion from contact of coal, and that cannot be protected by paint. The bottom plates or a hopper having a capacity of from one to three tons per foot, will last for more than ten years constructed of $\frac{1}{4}''$ plate. The side plates of the same thickness, about twice as long as the bottom plates.

This method of storage is favored for its convenience, protection from the weather, and for a reason more important than either of these, the security against interrupted supply, or the expense of extra labor in case of a breakdown of machinery.

Outside storage, when used alone, consists of either an independent bin, or one built along the front of the boiler house. The independent bin is unusual, except in connection with a small overhead storage.

Storage along the front of the building is a common method when the boilers are built in a single line. It is a relic of former days, when coal-handling machinery was not used, and the usual method was to run the cars onto a trestle along the building and discharge the coal in front of the boilers, where it could be reached by the shoveler. The trestle requires a long approach for the cars, which is often very undesirable, or even impossible, either on account of property lines or proposed buildings, or both. It is restricted to few localities for these reasons, as in large cities ground space is of such great value that overhead storage is very much cheaper. The cost of trestle and pocket alone is about the same as that of an overhead bunker of same capacity, and depreciation from $7\frac{1}{2}$ to 10 per cent.

Another form closely allied to the trestle and an outgrowth of that system, consists of a masonry pit, built the full length of

the boiler house, over which cars are run so that coal can be dropped into it direct. In this case it is transferred to the stokers by means of a travelling elevator, which may be moved from place to place, so as to receive the coal from any one of the several openings in the bin, and discharge it into the stokers.

The machinery alone for this arrangement in very long power houses does not cost as much per horse power as some other types in use, but increases inversely as the size of the plant.

The cost of it, including the preparation, excavations, foundations, structural work for supporting the track, necessary pit for the elevator and support for it, is larger than that of an overhead storage bunker, of the same capacity, with its supports. A bunker of this kind is durable, and a comparatively small amount of machinery is necessary. It lacks, however, the great advantages of the overhead storage system, where the coal being supplied to stokers by gravity, is entirely free from results of accidents. The coal is often frozen in the bin, causing additional expense in the handling of it. In case of breakdowns the coal has to be wheeled or shoveled. This is expensive on account of the location of the supply. The machinery has to be operated night and day to supply the stokers, requiring both day and night men, whereas, with overhead storage, the machinery may be made of sufficient capacity that a three or four hours' run in the day time will elevate enough coal to last for twenty-four hours.

An outside storage used in connection with an inside smaller one is the best possible arrangement where a very large supply is to be taken care of and where necessary ground is valuable. It may be either a trestle, a building or circular pile, which is tributary to a locomotive crane. A building is not advisable for larger capacities, and except for certain locations, is almost prohibitive, on account of expense, and even then it is more expensive than either of the other two systems. It has the advantage that it occupies a smaller space than the trestle having the same capacity. They are generally built near to the boiler house, and the machinery arranged to either take the coal from the car and distribute it in the storage, or from the storage to the overhead bunker in the boiler room. The maximum depth at which soft coal should

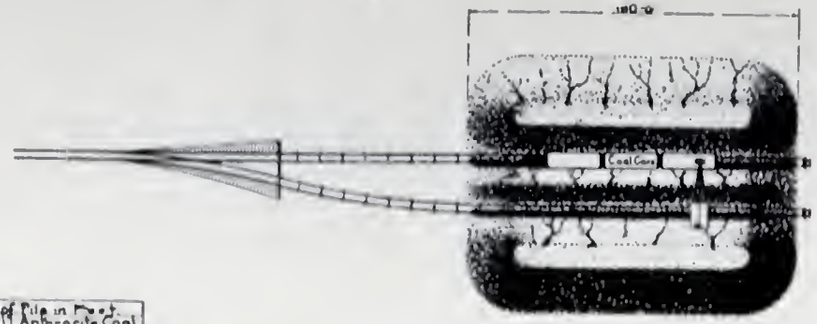
be stored varies from 15 to 30 feet, according to its tendency to spontaneous combustion. With a trestle, therefore, unless the coal is stored as shown in the illustration of this type of storage, it has to be very long in order to get the capacity. For instance, a pile 20 feet high allows a storage of only six to seven tons per running foot, making a 5,000-ton storage about 700 feet long. The company with which I am connected has developed several types of outside storage in recent years which have found general favor and are meeting with wide application.

Among others a standard locomotive crane in connection with a double trestle, is an exceedingly good arrangement for a small amount of outside storage. (Fig.1.) By it, for instance, 5,000 tons can be stored in the length of 100. The cost per ton for handling with this method is about $1\frac{1}{2}$ to $1\frac{3}{4}$ cents.

For outside storage of, say, 15,000 tons up, the circular storage with a locomotive crane offers the cheapest and most flexible plan. (Fig. 2.) The coal is stocked by discharging it into a central dumping pit from where it is taken and distributed over the stock pile by an automatic self-filling bucket, operated by a locomotive crane, traveling on a circular track, so that it is always tributary to the central dumping pit.

Having decided upon the storage method, the next question is the kind of machinery to adopt. The simplest, and usually the least expensive, consists of a receiving hopper, an elevator at one end of the building and a conveyor for distributing the coal in an overhead bunker. This was the general outline of the first installations ever made for this purpose, some of which are still in existence to-day. The designs were very crude and limited in size and capacity by the strength of the largest Ewart detachable chains manufactured at that time. There have been many variations made to suit local conditions and improvements made upon chains used for this purpose, but with slight alterations this design may still be made applicable to the majority of cases, although it is not always the best suited for the results desired.

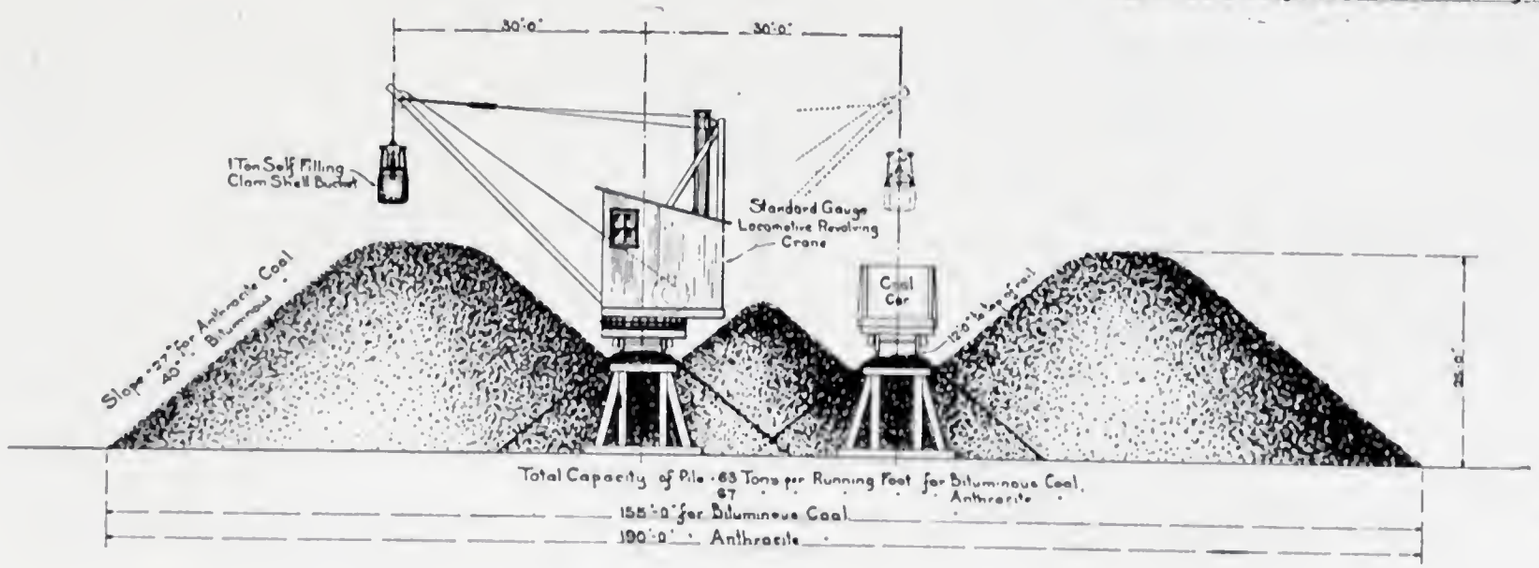
Taking this design in detail, the delivery track should be arranged so as to allow the coal to be dumped through the bottom of the car into a receiving hopper under the track, and should



PLAN OF COAL PILE & TRESTLES
FOR
10,000 Tons Bituminous Coal

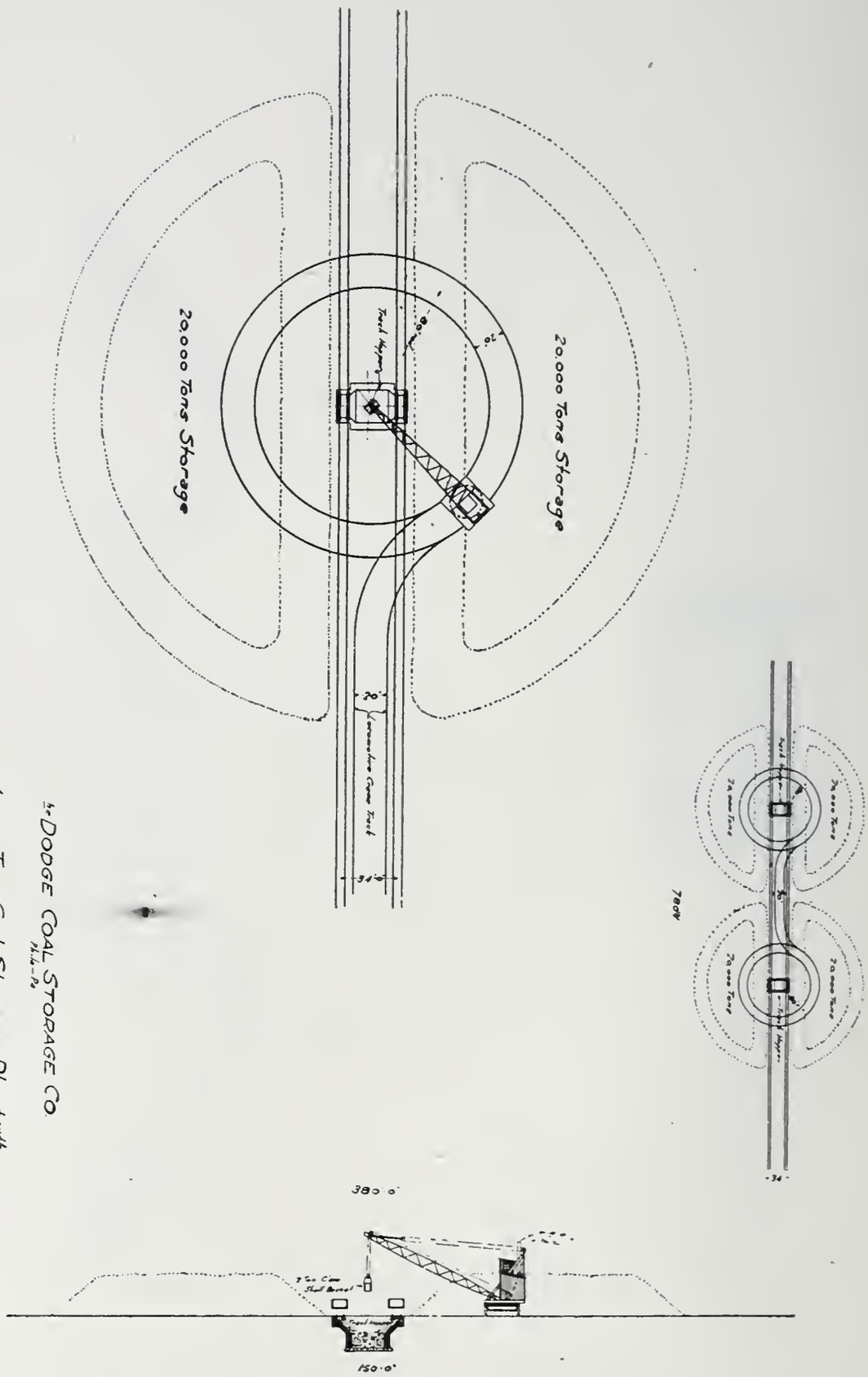
Total Capacity of Pile	Total Length of Pile in Feet. Bituminous Coal	Anthracite Coal
5000	110	125
7500	130	162
10000	190	200
12500	230	281
15000	270	274
17500	310	311
20000	360	340
Capacity of Pile per Running Foot	Bituminous Coal 63 Tons Anthracite " 67 "	

DODGE COAL STORAGE CO.
NICETOWN, PHILA.
Standard Coal-Storage Plant
WITH
Standard-Gauge Locomotive-Revolving-Crane on Trestle



CROSS SECTION THROUGH BITUMINOUS COAL PILE

Fig. 1.



Plan and Elevation of 40,000 ton Storage Pile. (Patented.)
Fig. 2.

have a slight grade to assist in the shifting of both the empty and loaded cars. If this is impossible, a power winch may be used to advantage.

To permit run-of-mine or lump coal to flow from this hopper freely and without jamming, the opening must be of such a large size that the coal will flow faster than the elevator or conveyor can take it away. The capacity of an elevating or conveying machine and immunity from breakdowns depends in a large measure upon the proper delivery of material to it. When the coal is in a finely divided state, it can be controlled by an ordinary sliding gate, but when it contains large lumps, it cannot be regulated uniformly in this way without the constant attention of a man.

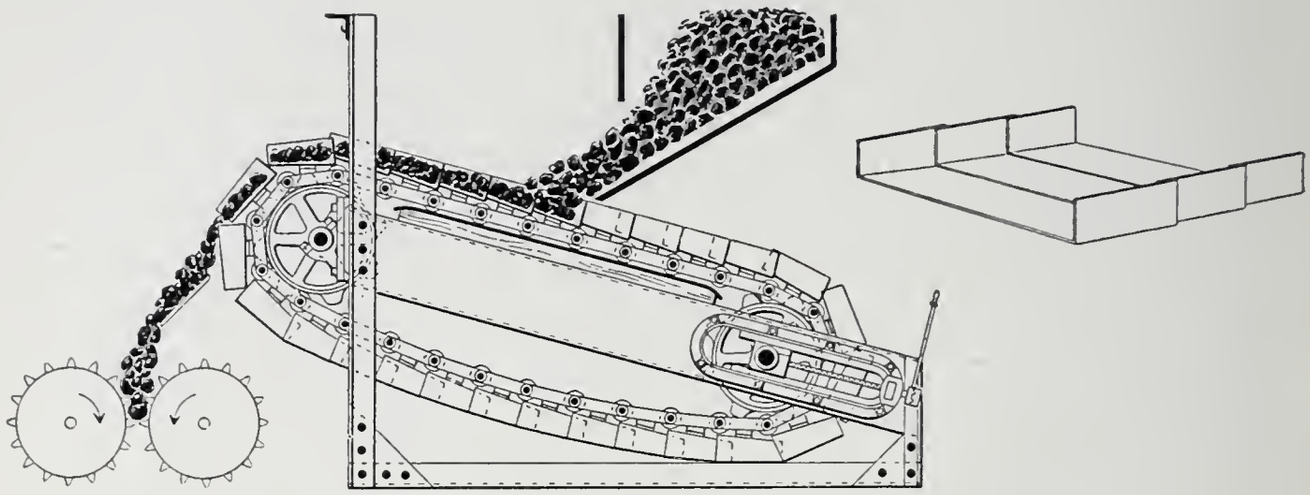
The problem of dispensing with this necessity has resulted in the development of several automatic feeding devices which regulate the flow of even the largest lumps as uniformly as desired. Among these may be mentioned the roll feeder, apron feeder and reciprocating gate.

The roll feeder, to my knowledge, was among the first developed, it having been used for several years in the ore refining plants of New Jersey for feeding ore to conveyors. It was found to be very efficient for this purpose. In its application to coal, the objection to it is the large diameter and consequent vertical height required on account of the large openings necessary for the proper flow of the coal from the hopper.

A very neat variation of this design of feeder is one constructed of cast iron. It consists of a sleeve made to fit a rotating shaft of a length suited to the capacity, having four blades radiating at right angles to each other. The space between blades fills with coal, which is discharged into a chute as it revolves. A roll feeder of this type occupies the least space of any of this class.

The apron feeder, (Fig. 3) which was the next development in this line, is virtually a roll feeder stretched out, that is, its longitudinal axis lengthened and transverse axis shortened sufficiently to prevent coal from flowing over it from the opening in the hopper when in repose. It is constructed of two chains having steel

corrugated or flat plates riveted on continuously, forming a steel belt, and is run at a slow, uniform speed sufficient to give the capacity required.



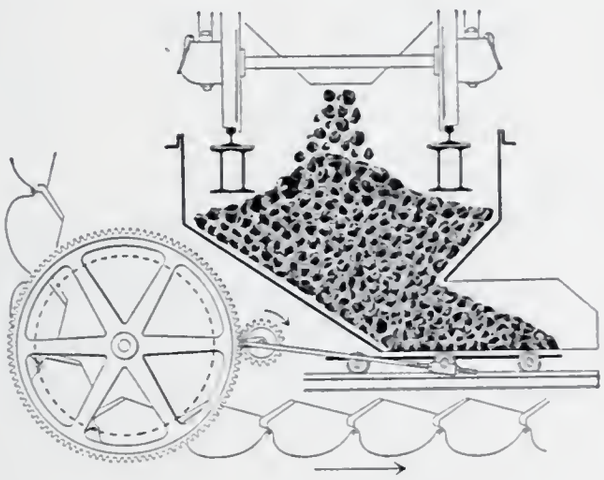
Continuous Apron Feeder.
Fig. 3.

The apron feeder acts not only as a regulator, but is very convenient as a conveyor in addition, at times, particularly if the dumping point is, say, ten or fifteen feet away from the elevator, in which case it serves the purpose of a conveyor as well as a feeder. It also has the advantage, when depth of pit is a consideration, that it may be inclined upwards, so that the foot of the elevator may be on about the same level as the bottom of the dumping hopper.

The reciprocating feeder, the simplest of the three, is a very efficient automatic regulator, perfect in its control of the delivery, and can be constructed of any size and capacity to handle lumps of any diameter whatever. As in the case of the other designs, the rate of delivery is entirely independent of the size of the opening in the hopper, and the latter can therefore be made large enough to suit any lumps to be handled.

The reciprocating feeder consists of a flat plate operating under the discharge opening of the hopper, and actuated by a crank mechanism connected with the conveyor or crusher. As commonly constructed by us, they are made with a quick adjusting devise to change the flow so that the capacity will suit the material handled.

As the crank shaft revolves, (Fig. 4) the apron is moved forward from position A. A portion of the material carried with it is discharged over the end when the apron is pulled back again to its former position by the crank. You will notice that when it rests in this position it extends slightly beyond the line of repose of the material and acts as a gate, checking any direct discharge from the hopper.



POSITION "A"

Fig. 4.

If the coal to be handled is large, it will be necessary to crush it to a small size before it passes to the bunker, so that it will easily enter the spouts leading to the stokers and be of the proper size for them. As large machinery is required to handle large lumps of coal, the crusher should be placed as near to the receiving point as possible, preferably under or near to the dumping hopper.

The crusher is usually of the two-roll toothed type. On account of the nature of its duty, it is constructed in a very rugged manner and provided with breaking device or springs to prevent disaster in case of pieces of wood or iron getting between them. Crushers act best when the delivery is regulated to them by the intervention of a gate of one of the above forms.

The elevators for taking the coal from the crushers to the overhead distributing conveyor are usually one of the two following forms: The gravity discharge or the continuous bucket. The gravity discharge consists of two strands of chain, with V-buckets

hung centrally between them. The buckets, after passing around the head-wheel, are carried horizontally for a short distance in a trough which retains the coal as it flows from the partly inverted buckets. The trough is fitted with a chute through which the coal is discharged into the distributing conveyor, or directly into the bunkers, if they are so small that they do not require a conveyor. The flow from an elevator of this design into the conveyor is such that the most gentle treatment of the coal that is possible is insured. For anthracite coal, therefore, this is a most perfect type of elevator, on account of the small amount of breakage. It is also one of the best designs that can be constructed for the handling of any coal in large lumps.

The continuous bucket type consists of a single strand of heavy chain, with the buckets bolted on continuously. They are of such a shape and so placed that the front of each bucket, when inverted, forms a chute and aids the fixed chute in receiving the discharge of the material from the next bucket following. The buckets are fitted with angles on the ends which run on stationary steel guides. These are entirely for the purpose of safety in the case of an emergency. This elevator alone has this advantage, as the buckets, being continuous, are threaded in the guides and cannot fall in a mass at the foot should the chain break, as is possible in the case of a double strand elevator with the buckets at intervals.

It forms a simple, rugged machine, with a very large carrying capacity and is unexcelled for handling steam sizes of anthracite coal. It has the added advantage that there is but one turn for the chain at the discharge point, where it is under the most severe strain. The chain has to make but one turn at the head to effect the discharge, whereas in the gravity type, two turns at least are necessary, and sometimes more. It is evident, therefore, that the life of the chain in the continuous bucket type is longer than that of the gravity type, when the strains per square inch of bearing surfaces in the chains are equal.

A valuable feature of the gravity discharge type that is sometimes convenient, is that the trough at the top may be exended

horizontally (Fig. 5) when the conveyor is not near the elevating point, and the conditions are often such that it may even be made to take the place of a conveyor altogether.

For distributing the coal from the elevator, there are four kinds of conveyors, screw, scraper, belt and continuous bucket.



Fig. 5.
Shows delivery from Gravity Discharge Elevator to Monobar Conveyor.

As screw conveyors are usually made, they are too light for the handling of coal, and never should be used excepting where small sizes are to be handled. Even then they should be constructed of very heavy steel on extra heavy pipe, or of cast iron flights, and run very slowly. The journals should be hardened and the bearings chilled and fitted with compression grease cups. Where screw

conveyors are favored, it is on account of the small space that they occupy, and for this reason, and their small expense, are often used for very small plants.

The scraper conveyor consists of either one or two strands of chains with scrapers attached at intervals, and running in a steel trough. It may be said that it does take more power than a bucket conveyor supported on rollers, or a belt conveyor, if there are no immediate trippers, each designed to carry the same amount of coal through the same distance, but this excess of power cannot be called a total loss, as there are some advantages to be gained by this design. The power required to run a properly designed and lubricated scraper conveyor empty is practically the same as that of an empty bucket or belt conveyor. This relation of power between scraper and belt conveyors exists only when there is no intermediate tripper or discharger. Tests show that with one tripper in a belt conveyor 100 feet long it requires about the same power when running empty as a scraper conveyor of the same length and capacity running loaded. Compared with a conveyor without trappers the difference amounts to but $2\frac{1}{2}$ to 3 horse power per 100 feet for conveyors of the same capacity. The design of the conveyor should be such that all of the moving parts are either supported on wearing shoes at the end of the flights, which may slide in lubricated guides or by rollers.

Conveyors with a single strand of chain are suitable only for the smaller sizes of coal. When large lumps are to be carried, the same design of scraper may be employed, but with two strands of chain, to allow space for the largest lumps. Fig. 6.

Another form of conveyor which gives very good results is one constructed of two strands of roller chains running in guides and having scrapers attached between them. In all the above designs the scrapers are suspended so as not to allow them to drag on the trough. All chain conveyors are very rugged, if designed properly, are of simple construction and durable and capable of standing an unlimited amount of abuse. Their first cost is usually lower than that of any other form, involving only a small outlay for repairs.

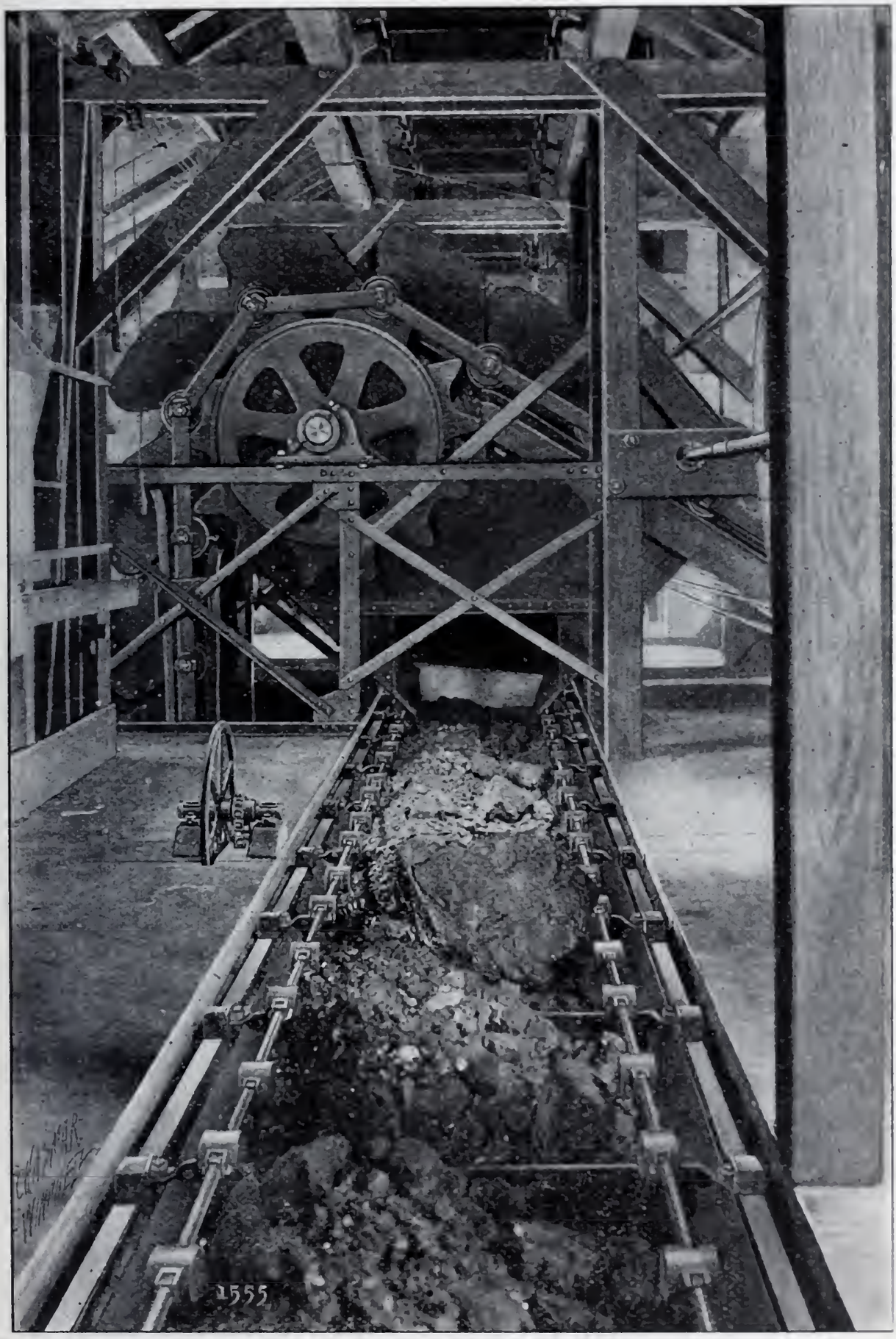


Fig. 6.

This cut shows Link-Belt Carrier delivering run-of-mine anthracite and bituminous coal (which has been automatically mixed below) into distributing conveyor, over bins, Erie Railroad Co.'s coaling station, Jersey City, N. J. Capacity of pocket, 2,500 tons.

The highest development of chain for scraper conveyors is what is known as the Monobar, (Fig.7), for the reason that it is simple, strong, very light—in fact, lighter for its strength than any chain in present use—easily adjustable, durable on account of its large bearing surfaces and inexpensive, on account of the bolts

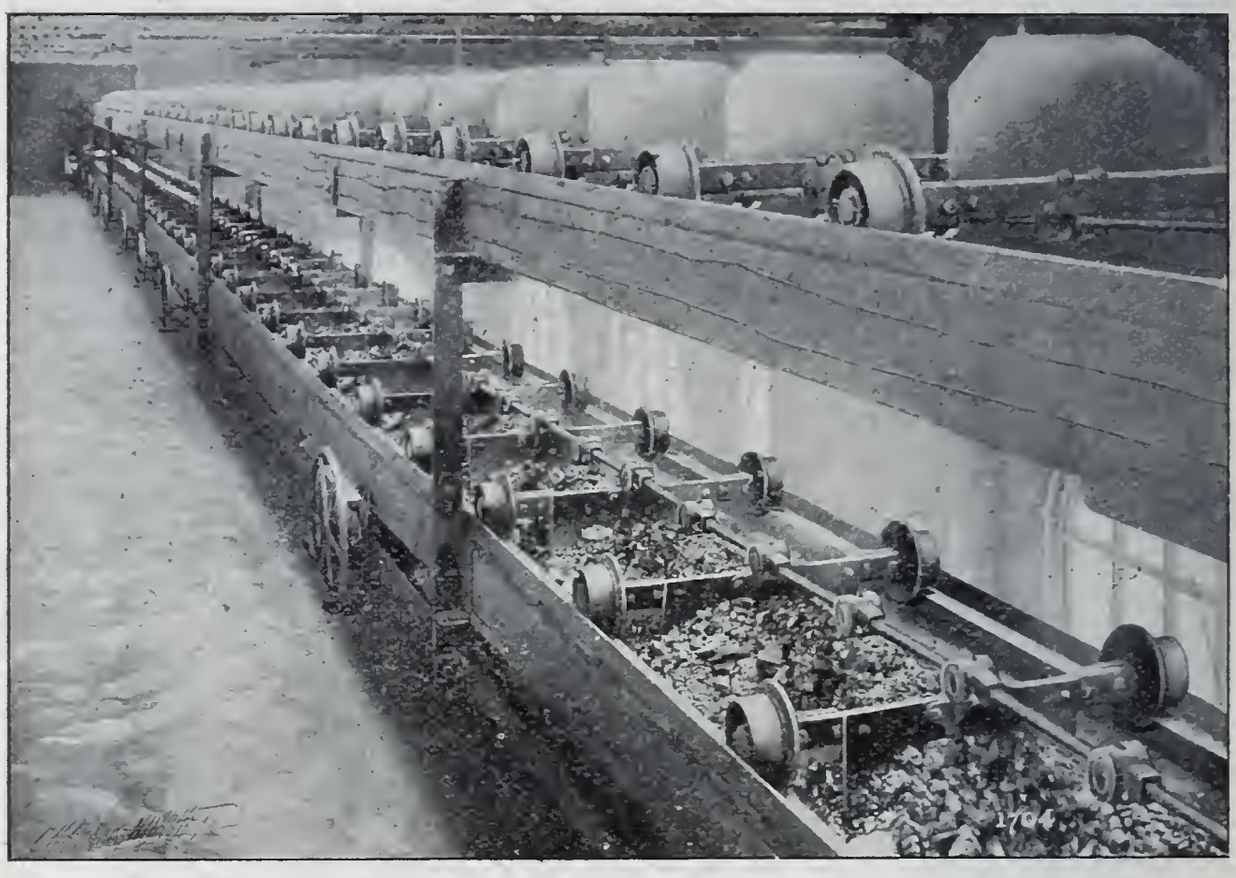


Fig. 7.

Monobar Roller Flight Conveyor (Motor Driven) in boiler house of Allegheny City Water Works.

being permanent and new joints being the only expense necessary in restoring the chain to perfect condition.

Belt conveyors, properly designed, and under certain conditions, prove highly satisfactory. It is being found by experience, however, that they cannot be applied to the best advantage to every condition. Properly constructed and with a belt chosen to suit the conditions, they are better in some cases than any other type of conveyor. Their success, as well as that of chain conveyors, depends upon the construction of the details. To give the best and most lasting results, the belt should not be excessively



Fig. 8.
Link-Bell Pivoted Overlapping Bucket Carrier (Patented) Handling coal and ashes in boiler house.

troughed, wearing parts should be thoroughly lubricated throughout and the belt of uniform section of either very flexible rubber or cotton.

No belts now in operation show greater durability than those running absolutely flat, as in grain elevators. The troughing makes a great difference in the length of life of a belt, and the nearer flat that it can be run to give the capacity, the longer service will it give. We erected some large grain elevators and conveyors 800 feet long for the P. R. R. Co. in Philadelphia four years ago, in which, with our new belt, was spliced 800 feet of 6-ply rubber belt that had been previously used for the same purpose for ten years. These belts ran flat. While they require less power, they have a large number of parts that are continually running at a very high speed, so that in comparison with a roller flight conveyor, the expense of repairs is considerably greater, on this account.

There are several kinds of bucket, pan and apron conveyors, and owing to the material of which they are constructed, are more durable and often more desirable than any other form of conveyor.

A form of carrier that has been used very extensively in recent years in the largest power houses is the pivoted bucket type, consisting of buckets suspended from shafts or pins running between two strands of chain. (Fig. 8.) There are several designs of this type of carrier, but the one shown differs from the others in the location of the pivot, which is attached to the extended arm on the inside of the chain link. On account of this when the buckets are passing around the sprocket wheels they describe a larger curve than the chain proper and separate to such an extent that there is no interference between the overlapping buckets, so that they are at no time, except when discharging, in any other position than a horizontal one. The discharge is effected by a movable dumping carriage. The accompanying illustration shows a typical arrangement of this type of machinery in a boiler house. Coal is received on a track running alongside the boiler house and is delivered into the carrier by an apron feeder. This arrangement is very simple, but on account of the very large weight of the machinery, the unequal wear in the two chains being

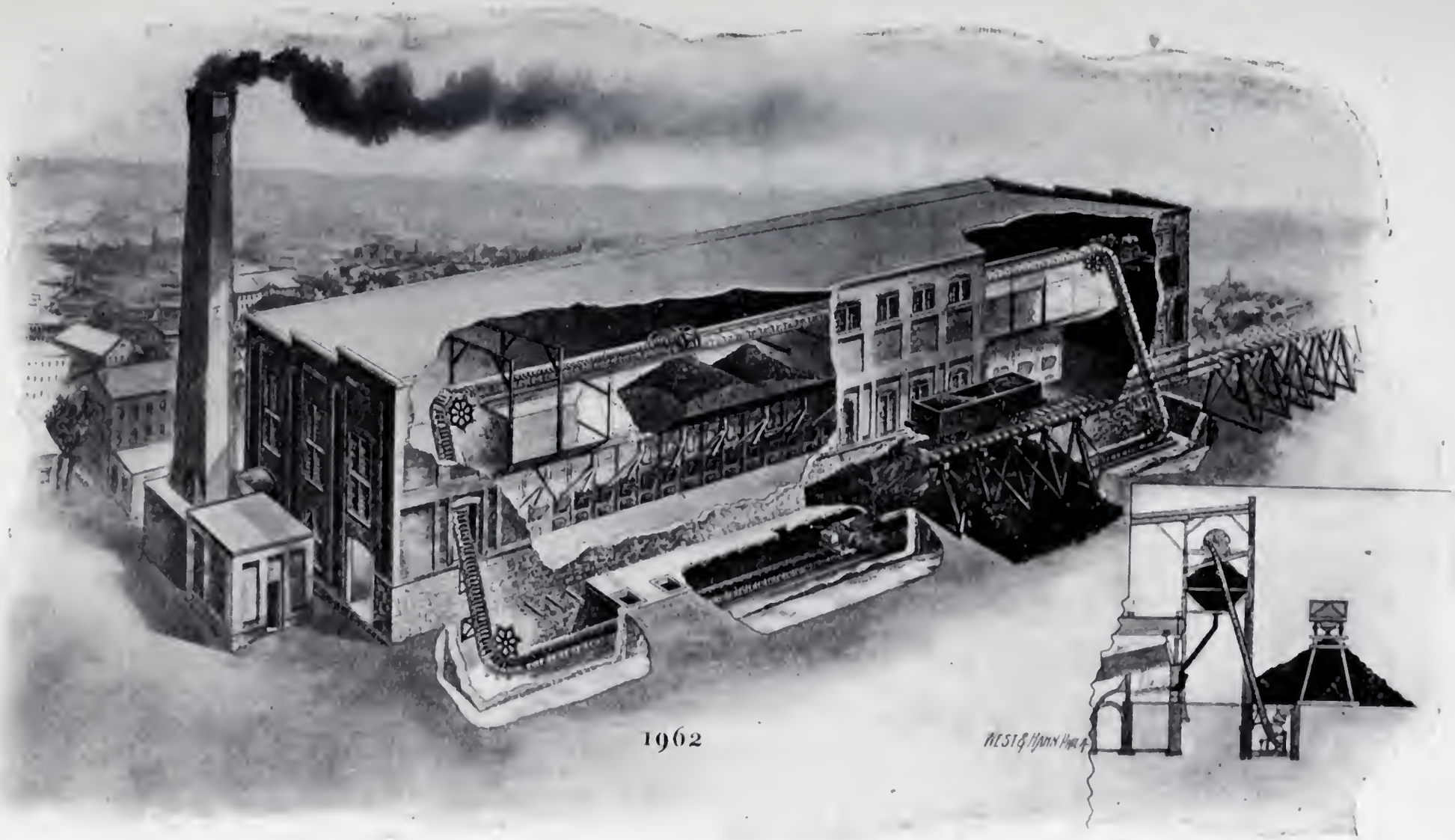


Fig. 9.

Link-Belt Transfer (Patented.) No. 2 Boiler House, Solvay Process Co., Syracuse, N. Y. Receives coal from storage under trestle, outside of building, and delivers it into overhead bunker inside the boiler house, at rate of 50 tons per hour.

great, there is difficulty in making such long strands of chain with material of sufficiently uniform quality that the two strands will wear equally. As usually constructed they are expensive to keep in repair.

The tendency now, in the largest power houses, is to return to the first methods, and to adopt the combination of a separate elevator and conveyor, except where coal and ashes both are to be handled by the same machine. The arrangement shown above is very convenient for this, but by handling ashes at the same time, the life of the moving parts is decreased at least two-thirds. The best way to dispose of the ashes and the cheapest in the long run is by means of a car.

Another form of conveyor, which is in successful use in connection with an outside storage and an auxiliary overhead one, is the "Link Belt Transfer." (Fig. 9.) It represents the culmination of effort to reduce to a minimum the dead weight of conveyor parts per pound of material carried. As designed, it will carry one pound of coal per pound of weight of the moving parts; therefore, it requires a very small space, smaller amount of wear, and the least possible consumption of power. It consists of steel buckets of rectangular cross-section, placed end to end with no intervening gaps, and attached at one side to a chain of the Mŏnobar type, around the bolts of which the buckets are free to swing. To prevent the coal from spilling on the vertical run, the buckets are fitted with internal diaphragms. The coal is discharged on the upper run by means of curved rail, supported on a movable carriage which forces the buckets to revolve on the chain bolt, turning them upside down.

Since the single chain is employed, the buckets are free to run in any path in which the chain can be led; therefore, they easily assume the position shown in the illustration; or it may run in any plane whatever between a vertical and horizontal. This feature is peculiar to this type of conveyor and makes a very desirable machine under the conditions just shown.

The transfer is the only link-belt carrier which will distribute material around a horizontal path, so that as a means for distributing material over rectangular areas it has a very wide field of usefulness.

STRUCTURAL SECTION.

A meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held in the auditorium of the Society building, at 410 Penn avenue, Pittsburg, April 28, 1903.

Meeting called to order at 8:25 p. m., 30 members and visitors being present.

Report of the Secretary read and approved.

Moved that the Secretary cast the ballot for the officers of the Section as nominated by the Nominating Committee, as follows:

Chairman—J. K. Lyons.

Vice-Chairman—Frans Engstrom.

Secretary—Willis Whited.

Directors—Morris Knowles, F. A. McDonald.

The subject for discussion was "Mill Buildings." The discussion was participated in by L. F. E. Hildner, Chas. Worthington, S. B. Ely, F. S. Rice, J. K. Lyons and others.

Subject selected for discussion at the next meeting, to be held May 26, "Office Buildings."

On motion Section adjourned at 10:50 p. m.

WILLIS WHITED, *Secretary.*

CHEMICAL SECTION.

The regular monthly meeting of the Chemical Section was held Thursday evening, April 23, 1903, the chairman, Mr. H. W. Craver, presiding. The minutes of the last meeting were read and approved.

No further business appearing before the meeting, the paper of the evening, "The Evolution of the Determination of Iron in Ores," by Mr. H. W. Craver, followed. After some discussion and reminiscences of early analysis and methods, the section adjourned.

CHAS. H. RICH,
Secretary.

THE EVOLUTION OF THE DETERMINATION OF IRON IN ORES.

HARRISON W. CRAVER.

The first methods of testing ores were dry or fire assays. These were early developed; in fact, must have originated soon after the smelting of ores was begun, for it was a simple step to introduce the system of carrying out smelting operations in miniature before undertaking workings on any considerable scale. Not until the sixteenth century, however, do we find many references to such assays; and at that time the methods were quite fully developed, so much so, indeed, that no great changes have since been made.

The art of assaying then formed a special branch of knowledge. It was the sole branch of chemical analysis practiced, the balance being already the chief instrument, and the simplicity and clearness of the methods showed a wide divergence from the strange operations of the alchemists and adepts. Thus, although used only by miners and smelters, assaying was in a way the starting point of modern chemistry, for exact chemical knowledge first began with the use of the balance for proving all chemical operations.

In general, the early assay methods were small scale reproductions in the laboratory of the smelting process to be employed. As the smelting of iron was a comparatively simple process the assay was also easily made. The first method of which we know was a simple crucible assay. The powdered ore mixed with charcoal powder was placed in a crucible and heated. A smith's forge or an assay oven in which the hearth was replaced by an iron ring was used. The crucible was placed in the ring, charcoal piled around and the fire blown by an ordinary leather bellows.

The chief object of the assay was the determination of the percentage of iron, but the same process could be used to deter-

mine the correct proportions of ore and fluxes in the smelters. This "burdening test," however, was little used in the sixteenth century.

The importance of a correct sample was well understood, and sampling done much as to-day. With a shovel, portions were taken from various points of the ore pile. These were re-piled and the process repeated; this sample was then powdered and mixed and from this the charge taken. This was mixed with the needed flux and charged in a crucible.

The chief sources of our knowledge of assaying in the sixteenth century are the writings of Georg Agricola and Lazarus Erker. In the seventh book of Agricola's great work on metallurgy, "De re metallica," he gives directions for testing iron ores. The sample is to be roasted, powdered, washed and dried. A magnet is then brought in contact with the ore and the adherent particles of iron brushed off in a crucible. This operation is repeated until no more particles are attracted by the magnet, when saltpeter is added as a flux and the crucible ignited until a button of iron is obtained. The readiness of the ore to cling to the magnet affords some idea of its richness or leanness.

In 1574 Erker published at Prague the first book dealing with assaying alone. His directions are practically a repetition of those of Agricola, although given in greater detail. In his chapter on testing iron ores he says: "Iron-stones can in no way be more easily and better tested than by the magnet. If you will thus test it, roast it, (though some take it unroasted), rub it fine and take a good magnet and wave or draw it through the ore. All the good iron hangs to the magnet; brush it off with a hare's foot and stir the iron stone again with the magnet as long as you can lift any with the magnet, until at last what remains will not hang; that is barren and not good stone. Thus you can see if a mine contains iron or if an iron-stone is rich in iron, for, as stated, the magnet raises no other metal, but iron and steel alone.

"Steel-stone, however, which is quite unlike iron-stone in color and some of which looks like a yellow spar, is, as is also some iron-stone, not lifted by the magnet when raw; one therefore roasts the steel-stone, when it colors to a shade like rich iron-

stone, the magnet then attracts it gladly, and more strongly and quickly than iron-stone."

The chief characteristics of these old iron tests is the preparation of the ores, particularly the roasting and the separation of the magnetic portion. In many respects the melting differed from that used to-day. The crucible used, as shown in Agricola's drawings, was the so-called Hessian crucible, circular at the base and triangular at the mouth. This was lined with a mixture of clay and charcoal 3 mm. thick, the usual proportion of the mixture being 33% clay and 67% charcoal. The mixture which effected the reduction, consisting of 25% clay and 75% charcoal, was then tightly packed in, leaving only a small central aperture for the sample and the flux, which had been previously ground together in a mortar. The fluxes used were such as would easily reduce the silicates present to a fluid glass; Agricola mentions saltpeter only. Later additions were made of such substances as lime, clay and sand, suggested by their use in blast-furnace burdens.

The smelting was usually carried out in a smith's forge before the blast. The crucible was luted with clay and covered with a charcoal cover, on which charcoal dust was heaped for further protection from the blast. The heat was gentle at first and increased gradually, about one hour being required for an assay. The weight of the button gave the yield of pig iron, while from its appearance and that of the slag some indications of the worth and properties of the ore could be drawn.

The knowledge of wet methods of iron analysis was entirely confined to a few qualitative tests such as that mentioned by Pliny, who speaks of tincture of galls as a reagent for iron. This was used by Paracelsus to detect iron in mineral waters. An interesting test for impurities is given by Vanuccio Biringuccio, who was the first important writer on metallurgy among the Latin races. This test consisted in placing the ore in a "strong pickle" (nitric acid), and after removal drying it over a fire and observing the color of the fumes. Or the ore was allowed to remain in the acid for a longer time and then a stream of air was blown through the liquid, the bubbles showing the presence of copper.

An official assay office was opened in Nuremberg in the first half of the sixteenth century, in which special attention was given to ores.

During the seventeenth century no advances of any moment seem to have been made in assaying. The fire assay remained the only available test.

In 1697 a work on testing was published in Dresden by Christian Carl Schindler. He gave directions for iron assays as follows: "Take iron or steel-stone, rub it fine, weigh out two centners, (assay centners or hundredweights) and roast thoroughly. When cold, divide it. To one part add 2 centners of black flux, 1 centner of sal ammoniac, $\frac{1}{2}$ centner of glass-gall and $\frac{1}{2}$ centner of finely powdered charcoal, mix well together, cover well with salt and heat in the blast for a full quarter of a hour." Or "1 centner roasted iron-stone, 1 centner lead-glass, 2 centners black flux of 2 parts saltpeter and one part argols, and $\frac{1}{2}$ centner finely powdered charcoal." Or: "Take two quarts of old stinking urine, and add a handful of pulverized argols and the same quantity of glass-galls or potash, and boil down until solid: then powder and use 6 centners of this flux to 1 centner of iron-stone. Cover with salt, and ignite for a full quarter of an hour.

In the eighteenth century the fire assay was the only analytical method until the latter quarter of the century; and even then the little knowledge of wet methods extant was confined to a few chemists.

One of the important works of the century on assaying was Johann Andreas Cramer's "Docimasia," published at Leyden in 1739. A revised edition appeared in 1743 under the title "Elementis artis docimasticae" and was translated into English and French.

Cramer rejected the test with the magnet and remarked the unreliability of the crucible assay for iron in comparison with that for other metals. He says: "A very strong and long continued heat is necessary to form the reduced iron into a dense regulus. As there is no certain indication when this is accomplished, and as longer heating than necessary causes a notable amount of iron to go back in the slag, the test is always uncer-

tain." Cramer also hammered the button to obtain some idea of its quality.

The next considerable advance in our knowledge of the analytical chemistry of iron was due to Bergman's investigations. Torbern Bergman (1735-1784) was professor of chemistry in the University of Upsala from 1767 until his death. He contributed much to our knowledge of analytical chemistry, his books and papers containing the results of much original investigation and giving clear, practical directions for the analysis of many inorganic bodies.

Up to this time the use of wet methods of analysis had scarcely been attempted. Their introduction by Robert Boyle at the end of the seventeenth century had not led to further development, and apparently their only application was to the analysis of mineral waters. In this case, however, they were only used qualitatively. Bergman first gave an extensive survey of the value of reagents and their effect. He gave directions for the course to be followed in a chemical analysis, and introduced the method of converting constituents into compounds of known composition and easy isolation rather than attempting to isolate those present. He made the first complete analysis of a mineral water, using practically the method in use to-day. He also studied the use of the blowpipe in determining minerals, and the art of blowpipe analysis of to-day rests on Bergman's directions.

The chief value of Bergman's labors lies in the methods he invented and by means of which he greatly increased the extent of the field of chemical research. The results of his quantitative analyses have proved rather inexact, although during his lifetime his fame as an analyst was such that his results were never disputed.

Bergman's method for iron was as follows: The iron ore was powdered as fine as possible, weighed out in a glass flask and digested with a mixture of one part nitric acid and two parts hydrochloric acid for some days; at boiling if the ore was difficultly soluble. The insoluble residue was filtered off on a blotting paper filter, washed with hot water and ignited. The filtrate and washings were combined and the iron precipated with "blood-

lye." This was prepared according to a method discovered by Macquer from white flux (argols and saltpeter ignited together) and Berlin blue. This "blood-lye" was added to the iron solution drop by drop until no more blue precipitate formed. A slight excess of the reagent was then added and the precipitate allowed to settle. It was then filtered, washed with hot water, dried, weighed, the weight of the filter subtracted and the amount of iron calculated from the weight of the Berlin blue. From numerous experiments Bergman found that one part of iron in the solution corresponded to six parts of Berlin blue and used this as a foundation for his calculations. The results by this method were much closer to the true values than by the crucible assay.

For common analyses Bergman considered it sufficient to dissolve the ore in acid, neutralize, and then find the amount of lime necessary to precipitate the iron. From this the iron was calculated.

The end of the eighteenth century found the analysis of ores and the determination of iron still in a poor condition. Lack of knowledge of the processes of oxidation and the oxids and hydroxids of iron prevented the correct calculation of analyses; and the faulty methods of analysis contributed in still greater degree to poor results. As the fire assay was still the common process, and as this gave a cast iron button, the results were ever high. The remaining constituents were determined and the resulting difference called oxygen. Bergman's method of precipitation as Prussian blue (ferric ferrocyanid) also gave high results, and as incomplete washing, etc., usually caused high values for other constituents the sum of an analysis usually exceeded 100%. This value the chemist usually reduced to 100% according to his preconceived ideas, thus still further reducing the worth of the work. The first chemist who had sufficient courage to publish the actual results of his iron analyses was Klaproth (1743-1817).

The only change in the fire assay, which still retained its popularity and was considered superior in exactness to the wet assay, was in the use of more difficultly soluble fluxes. Guyton de Morveau, Kirwan and Chaptal give the same flux, glass and

borax being the chief ingredients. Mushet gives the following recipe as being furnished him about 1794 as the most perfect then known in England:

"Two ounces of iron-stone calcined.

"One ounce of pouynded bottle glass.

"One-half ounce of limestone pouynded smale.

"Mix up and melted, and then stir up with an iron rod for two or three times, and if the regulus appears thin and hot the separation is made, if not put in ¼ ounce of Pott Ashe and stir up again, and then draw the pott and let cule, and the metal button will be found at the bottom."

This was given as applicable to every iron ore.

We have some data which give an idea of the results obtained by these assays. Kirwan gave as the results of the analyses of magnetite the iron as equal to 80%, (pure magnetite=72.4%). Lampadius, in his Huettenkunde (1801-1810) questioned this result and considered it low, as his own assays gave 89% iron. He also questioned Kirwan's results of 70% to 76% iron in red hematite (pure hematite=70% iron), as he had obtained a value of 80% iron by fire assay.

In 1839 a method was published by Fuchs which was short enough to replace the fire assay in practical work. This method was based on the observation that hydrochloric acid did not attack copper when excluded from the air, but that solution occurred if ferric chlorid was present, ferrous and cuprous chlorids resulting and the amount of copper dissolved being proportional to the ferric chlorid present. The iron could therefore be calculated from the loss of weight of the copper.

This method was the leading one until about 1846, when it was replaced by the permanganate method, which was invented by Marguerite. His directions called for solution in hydrochloric acid and reduction with sodium sulfite. In 1862 J. Loewenthal and F. Lenssen announced that this method was inexact when carried out on a solution containing hyrochloric acid, and that it gave correct results only when the iron was present as sulfate, and sulphuric acid the only free acid. About the same time Fresen-

ius gave directions for use in cases where the use of hydrochloric acid could not be avoided.

The reduction of ferric solutions by zinc was discovered previous to this time, but in 1862 Mitscherlich first gave exact directions for its use.

The bichromate method made its appearance in 1850, the discoverer being Dr. Penny, of Glasgow. He used sodium sulfite as a reducing agent.

The other methods used for iron determination are the stannous chlorid method and the Zimmerman-Reinhardt method. The introduction of the first seems to have been due to Fresenius, and was published about 1865. The latter was published in 1884. To Zimmerman was due the introduction of manganous sulfate as an aid in titrating hydrochloric acid solutions with potassium permanganate, while Reinhardt suggested the method of reducing with stannous chlorid and taking up the excess with mercuric chlorid. In 1888 he also introduced the addition of sulfuric and phosphoric acids to the manganous sulfate.

These methods are in all essentials the ones in common use to-day. The only changes have been minor variations and the formulation of rules to insure uniformity of manipulation and results. As now used they leave little to be desired in the way of speed, ease of manipulation and accuracy.

Department of Technology.
Carnegie Library of Pittsburgh.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The 235th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's House, 410 Penn Ave., Pittsburgh, Pa., Tuesday evening, May 19, 1903. The President, Mr. C. B. Albree, was in the chair, and 110 members and visitors present.

The meeting was called to order at 8:15.

Minutes of the preceding meeting were read and approved.

The following applications for membership were reported as passed by the Board of Direction:

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY
ARCHIBALD ALSTON, JR.,	Head of Die Dept., Pressed Steel Car Co h., 514 Lincoln Ave., Bellevue, Pa.	M. G. Blest, J. E. Tesseyman, W. M. Peach.
LOUIS L. BANKS,	Supt. and Agent of Park Bldg., Pittsburg, Pa. h., 5433 Kincaid Street, Pittsburg, Pa.	D. Ashworth, D. Hunter, Jr., J. M. Dearle.
JAMES O. BARNETT,	- Purchasing Agent, - United Engr. & Foundry Co., Pittsburg, Pa. h., Parnassus, Pa.	F. I. Ellis, G. W. Knotts, K. C. Gardner.
EMIL E. BERTHOUD,	- Draughtsman, - Heyl & Patterson. h., Hotel Boyer, Pittsburg, Pa.	F. V. McMullin, C. W. Laing, W. M. Alston.
CRAIG R. BRANSON,	- Special Apprentice - of The Penna. Lines West of Pittsburg h., 4120 Allegheny Ave., Allegheny, Pa.	M. A. Tenney, F. V. McMullin, G. T. Barnsley.
JOHN T. BROWN,	Vice Pres. & Gen'l Manager, Damascus Bronze Co., Pittsburg, Pa.	I. W. Frank, T. J. Bray, Jr., C. W. Ridinger.
DAVID H. CAMPBELL,	- Borough Engineer - of Sewickley, Pa. h., 19 Chestnut Street, Sewickley, Pa.	F. A. Ensign, H. E. Horley, C. W. Ridinger.
EBEN B. CLARKE,	Gen'l Manager & Treasurer, Firth-Sterling Steel Co., Pittsburg, Pa.	A. G. McKenna, C. V. Wheeler, J. M. Camp.

STEPHEN P. COBB, - Draughtsman, - { M. W. Storer, P. Brynn, J. M. Elliott.
Elliott & Baton, Keystone Bldg., Pittsburg, Pa.
h., 302 N. Highland Ave., Pittsburg, Pa.

HARRY W. CHAMPION, - Secretary, - { C. B. Albree, F. A. Estep, F. S. Martin.
Newton Machine Tool Works,
24th and Vine Sts., Philadelphia, Pa.

HENRY C. CRONEMEYER, Asst. Special Engineer, { C. W. Bray, G. C. Mors, F. L. Wadsworth.
Edgar Thomson Steel Wks., Braddock.
h., 3001 Cliff Street, McKeesport, Pa.

FRANK DITCHFIELD, Pressed Steel Car Co., { J. E. Tesseyman, M. C. Blest, J. MacNulty, Jr.
Pittsburg, as Asst. Chief Engineer.
h., Laurel Ave., Bellevue, Pa.

ERIC C. ERICSON, Principal Asst. Engineer, { T. H. Johnson, D. Y. Swaty, B. V. Sommerville.
Penna. Lines West of Pittsburg.
Union Station, Pittsburg, Pa.

EDWIN S. FICKES, Chief Engr. Pgh. Reduction { D. H. Childs, Chas. Worthington, L. J. Affelder.
Co. and Northern Reduction Co.
Pittsburg Reduction Co., Pittsburg, Pa. h.. Parnassus, Pa.

ROBERT L. GRAVELEY, Asst. Sub-Way Engr., { G. K. Smith, C. R. Hilberry, R. M. Morganstern.
C. D. & P. Telephone Co.
h., 1205 Esplanade Street, Allegheny, Pa.

CHAS. H. GLASSOR, Mechanical Draughtsman, { W. M. Alston, W. H. Cornell, F. V. McMullin.
Pressed Steel Car Co.
h., 3 Luray Street, Allegheny Pa.

FRANKLIN COHEEN, - Manufacturer, - { L. L. Knox, F. M. Bowman, S. E. Diescher.
Canton, Ohio.

ELLIS J. HANNUM, - Asst. Secretary, - { C. B. Albree, F. A. Estep, F. S. Martin.
Newton Machine Tool Wks., 24th and
Vine Sts., Philadelphia. h., 2022 Brandywine St., Philadelphia, Pa.

ROBERT LEO MERAY, - Chief Clerk - { G. F. Freed, C. B. Albree, S. Diescher.
to District Engr. of the B. & O. R. R.
h., 1115 Bidwell Street, Allegheny, Pa.

WILLIAM B. KLEE, - President, - { I. W. Frank, T. J. Bray, Jr., C. W. Ridinger.
Damascus Bronze Co.
h., 1505 Shady Ave., Pittsburg, Pa.

CHAS. T. KLINGELHOFER, Superintendent, { G. E. Klingelhofer, C. B. Connelley, E. Fitzgerald.
American Foundry & Con. Co.
Frick Bldg., Pittsburg, Pa.

KARL E. LINK, - Superintendent, - { G. T. Barnsley, C. B. Albree, S. Diescher.
and Representative of Architect for Wabash Station.
h., 705 Fitzsimons Bldg., Pittsburg, Pa.

JAMES L. MOORE, - Designer, - { F. Hodgkinson, W. J. Auburn, Richard Hirsch.
with Westinghouse Machine Co.
h., 533 Collins Ave., E. E., Pittsburg, Pa.

WILMOT McCORMICK, - City Salesman - { F. J. Shaler, S. Diescher, B. E. Hobson.
for Wiseonsin Graphite Co.
h., 206 Carroll Street, Allegheny, Pa.

DUNCAN MacDOUGALL, Pgh. Steel Foundry, { L. L. Knox, L. F. Hildner H. M. Wilson.
Glassport, Allegheny County, Pa.

JAMES R. McGRAW, - Asst. Engineer, - { G. T. Barnsley, C. B. Albree, S. Diescher.
in M. W. Dept. P. R. R. of The B. & A. Div., A. V. R. R. h., 420 D Street, Oakmont, Pa.

CHAS. C. NEWTON, - President, - { C. B. Albree, F. A. Estep, F. S. Martin.
of The Newton Machine Tool Works, 24th and Vine Sts., Philadelphia, Pa.

JAMES B. REED. Supt. Pgh. Trolley Pole Co. { C. B. Albree, J. D. Biggert, S. M. Kintner.
and Keystone Forge & Machine Wks.
h., 312 Gross Street, Pittsburg, Pa.

OTTO ROTHENSTEIN, Mechanical Draughtsman, { W. P. Flint, E. S. McClellend, Richard Hirsch.
Westinghouse Machine Co.,
East Pittsburg, Pa. h., 211 Trenton Ave., Wilkinsburg, Pa.

RALPH B. ROSE, With Carnegie Steel Co. { C. V. Wheeler, A. G. McKenna, J. M. Camp.
h., 1131 Ridge Ave., Allegheny, Pa.

CHAS. H. SAMPLE, - Superintendent - { John Hare, F. B. Ward, J. W. Landis.
of Shops, Carnegie Steel Co., Donora, Pa.

AUGUSTUS M. SAUNDERS, Superintendent { G. V. Wheeler, A. G. McKenna, J. M. Camp.
of Nat. Tube Co., McKeesport, Pa.
h., 516 N. Park St., McKeesport, Pa.

JOS. W. STEVENSON, With The McClintic-Marshall Construction Co. { W. M. Alston, F. V. McMullin, F. Engstrom.
h., 7712 Edgerton Ave., Pittsburg, Pa.

W. A. WELDIN, - Draughtsman, - { F. Z. Schellenberg, L. C. Weldin, S. M. Kintner.
with L. C. Weldin, C. E., 604 Friek Bldg., Pittsburg, Pa. h., 747 Hill Ave., Wilkinsburg, Pa.

CHAS. A. WHIPPLE, - Draughtsman, - { F. V. McMullin, M. L. Rogaliner. F. S. Austin.
with Heyl & Patterson.
h., 125 Sherman Ave., Allegheny, Pa.

ROBERT C. WINLO, Inspector for Engineer'g Dept., { W. M. Peach, J. MacEnulty, Jr., A. Stucki.
Pressed Steel Car Co., Allegheny, Pa.

Moved and seconded that the Secretary cast a ballot electing the above named gentlemen members of the Society. Motion carried.

THE PRESIDENT—At the last meeting a committee was appointed to pass resolutions regarding the death of Mr. Card. Mr. Taylor and Mr. Chas. F. Scott were appointed on that committee. Neither of these gentlemen being present, that matter will come up later.

At the last meeting I called to your attention the proposed meeting next year in this country, of the Society of Chemical Industry. Heretofore the meeings have always been held in London or some place abroad. The Chemical Section will take a great deal of interest in this meeting, and after the meeting in New York the members are to visit several of the representative cities, including Pittsburgh. It is desired to appoint a committee from the Engineers' Society to co-operate with the other committees. The chair will appoint on that committee, Dr. Stahl as chairman, Mr. H. K. Porter, Mr. Geo. Macbeth, Mr. Emil Swensson and your President. Dr. Stahl will announce, probably to-night, the names of five other gentlemen from the Chemical Section who will also represent the Engineers' Society upon the arrival of the visitors next year. We are taking this action early, so as to be well prepared.

DR. STAHL—We will decide the matter next Thursday, and I will make the announcement after that.

THE PRESIDENT—It is with great pain that I announce tonight the death, at an old age, of perhaps the foremost manufacturer in Pennsylvania to-day, Mr. B. F. Jones. Not only those who have lived in Pittsburgh, but people all over the country have heard of Mr. Jones,—a man who stood for everything that is good in business; a man who in a span of years that many of us would like to equal, was never known to do a dishonorable thing; a man who succeeded by reason of his push and ability; a man whom all of us honor, and who was a member of our Society. I desire to appoint a committee to draw up proper resolutions regarding his death.

It was moved and seconded that a committee of three be appointed to draw up proper resolutions regarding the death of Mr. Jones. Motion carried.

THE PRESIDENT—I will appoint Mr. Discher, Mr. Ralph Crooker, and Mr. E. K. Morse, who will report at the next meeting.

We will now hear from Mr. Barnsley, of the Reception Committee.

MR. BARNSLEY—Mr. President, it is rather of necessity that I make a report. The first thing, I want to express my regret at the small attendance at the dinner to-night. We had an attendance of 35 out of some 800 members. One gentleman at the dinner consoled us by saying that we 35 were the only good fellows in the Society. While I would not like to think that all the others were no good, yet I would like to know why they do not attend. As it is my duty to cater to the members of the Society, I have no right to force upon them a dinner.

I announced in the May Bulletin that there would be a smoker on the 30th of this month. In deciding upon that date we overlooked the fact that it was Decoration Day, and it has occurred to us that perhaps some of the members of the Society might object to having the smoker on that date. If there are any objections we shall be glad to change the date; but if not, that date will stand.

At the last regular meeting I made a preliminary announcement regarding an excursion June 20th. I now have to announce that that excursion of June 20th is one of fact. We will have a general excursion on the 20th of June. That will be Saturday afternoon, between the hours of 2 and 10 P. M. on the river. Now this general excursion will include members, their wives, their sweethearts, and a few of their friends whom they wish to participate. We hope the ladies will surely be in evidence. It gives me great pleasure to say that this excursion is a complimentary one from the river interests. (Applause.) It is purely a complimentary excursion tendered us by the river interests. Everything will be done to make the Society have a great, good, and glorious time. Just which way we will go on the river I will not announce to-night. I will announce that after the gang plank is up. That

means that the members must begin to gather on the boat about 1 o'clock. We will go on the steamer Mayflower.

THE PRESIDENT—Gentlemen, this announcement from Mr. Barnsley makes a fitting climax to his efforts in our behalf. Our visit to the Iron City Brewery the other night was extremely interesting. We had some beer,—some very good beer, too,—but we had some engineering experiences there that were eye-openers, as well as the beer. Kindly remember this excursion.

MR. BARNSLEY—Referring to the river excursion, I will send out some printed notices, perhaps return cards, for those who want to attend.

THE PRESIDENT—The House Committee have reported that they have secured a tenant for our downstairs rooms, satisfactorily guaranteed as to payments, etc., and we will hereafter receive an income from this source; and also, they have proceeded with the instructions of the Society, to fit up the upstairs rooms for the storage of papers.

THE PRESIDENT—I have before me a list of papers for tonight, any one of which could fill the entire evening, and with profit, but unfortunately we have only one evening, a rather warm one at that, so we are obliged to cut the gentlemen down to about ten minutes each. We have a number of papers, and I will not take any of your time telling you how little I know about them. The first paper will be "Advance in Modern Steel Construction," by Mr. L. F. W. Hildner, of the Riter-Conley Co. of this city.

ADVANCE IN MODERN STEEL CONSTRUCTION.

BY L. F. W. HILDNER.

In July, 1902, Professor Jacoby, of Cornell University, read a paper before the Association for the Advancement of Science on "Recent Progress in American Bridge Construction." In this very interesting paper he calls attention to the changes of design, the changed methods of construction, the increased methods of loading now commonly applied to railroad bridges. He points out that in the ten years just passed the loading requirements for uniform loads have risen practically from 4,000 to 5,000 pounds

per foot of track, and that this has been due to the adoption of the 100,000 pound car by many of our railroads. In the plate girder bridges have been adopted in many cases for lengths above 100′ 0″, and the riveted truss used for lengths from 100 to 150′ and even up to 180. The use of solid floors of various descriptions has become almost general.

In his paper Prof. Jacoby calls attention to many of the large projects in bridge building in progress, and gives at length a list of the most important bridges of the various classes now in existence, the plate girder, riveted, pin, cantilever, suspension and arch bridges, draw spans and rolling bridge spans.

He calls attention to the increasing use of reinforced concrete bridges instead of those of steel, especially for shorter spans in all classes of work, and also the frequent construction of stone arch bridges.

We have all been interested in the moving and the replacing of old bridges by new ones in incredibly short spaces of time. We have in our own city seen this done on the old Fort Wayne bridge and others.

Accidentally an old lithograph of the Hannibal Bridge built in 1871 came to my notice several days ago, and is herewith presented. In design it is a double intersection. It shows the cast iron top chord. The posts are latticed channel, the floor beams I beams. If I am not mistaken this bridge has been recently replaced.

If any of you are interested in old structures, an ancient type can be seen at the present day spanning Woods Run under California avenue, Allegheny. The most interesting point in this bridge is the hog-chained post.

It was in the beginning of last year, I think, that an Englishman came to this country to see how and why the Americans could outbid his countrymen on bridge work. His report was not the most reassuring for the English manufacturers. The discussion which followed the reading of his conclusions before a meeting of his colleagues on his return was, to say the least, amusing. One man did not believe in multiple drills because he had used them 30 years before and they had not been a success. One

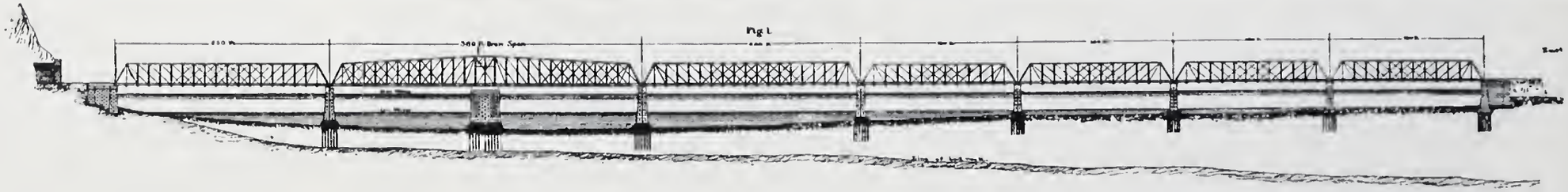
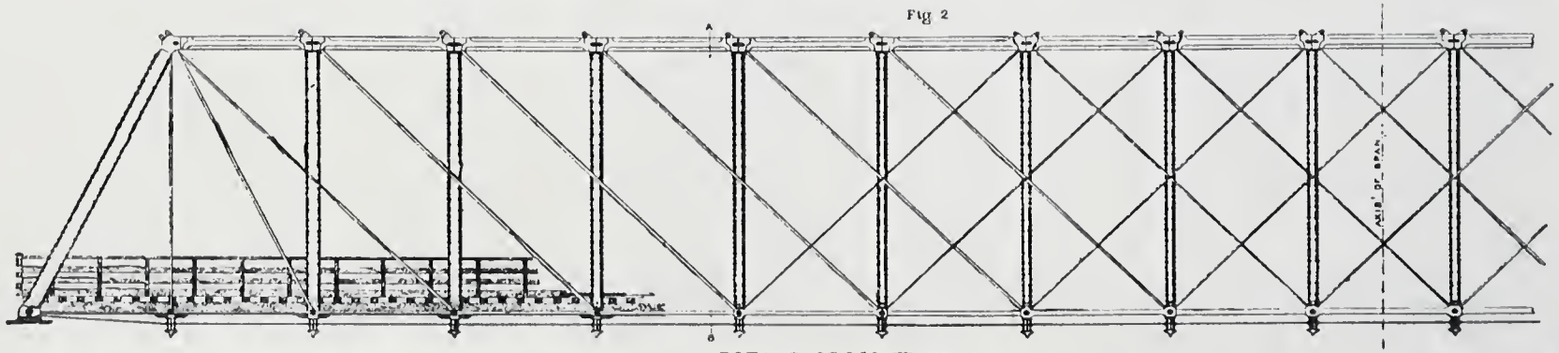
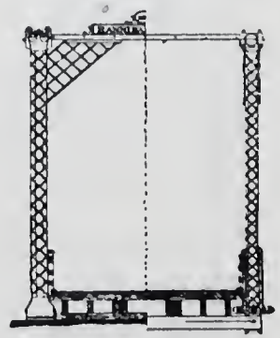


Fig 1.

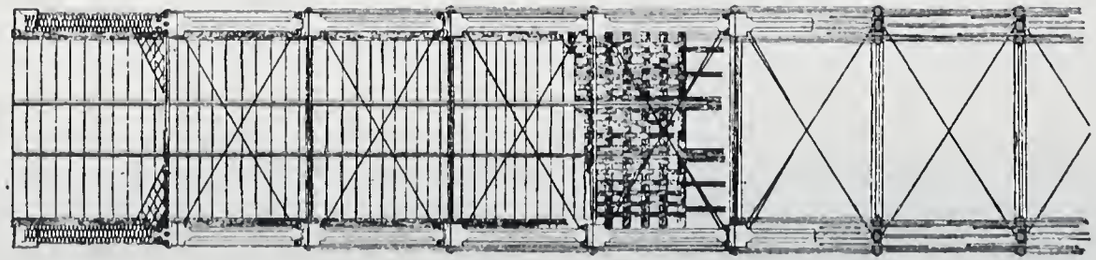
Fig 2



DETAILS OF 250 FT SPAN



END VIEW SECTION AT AB



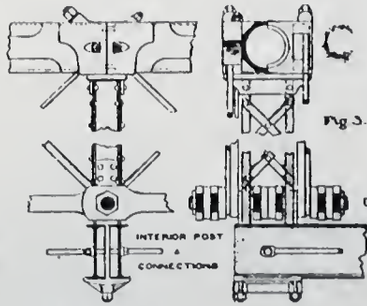
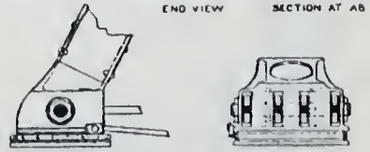


Fig 3.



END PEDESTAL

INTERIOR POST & CONNECTIONS

SCALES

Fig 1 .....

Fig 2 .....

Fig 3 .....

IRON BRIDGE OVER MISSISSIPPI RIVER AT HANNIBAL, MO.

BUILT IN 1871 BY DETROIT BRIDGE AND IRON WORKS

OF DETROIT, MICH.

man said that our shops were not bridge shops but simply girder shops, etc., from which pieces were sent out to the field to be there assembled. Another did not believe in standardizing, etc.

This Englishman's conclusions were based upon close observation and calculations. His calculations showed that for seven years extending from 1895 to 1901, taking the Pencoyd shop as a model, that an American shop would show the following result: A draftsman would turn out an average of 770 tons per year, a templet maker 2,375 tons, a bridge shop worker 115 tons, a forge shop man 35 tons and an eye bar shop man 160 tons, whereas the English shops could show a result like 1,000 tons for a draftsman, 500 tons for templet maker and 20 to 30 tons for a bridge shop worker. This comparison showed two things, first that the English workman has his superior in the American, and second, that the English shop has its superior in the American because of the use of brain in planning the work more fully in the draughting room. You will note that an English draftsman will stand for more tonnage per year than an American, but the difference in the work turned out by the shops clearly shows us that the work is better prepared when it reaches the workman.

It was not my intention to follow out this subject along the lines of Prof. Jacoby's papers, but rather along the lines laid down by Mr. Molesworth's (the Englishman above referred to) conclusions.

It is a self-evident fact that the American's bridge and structural shops, including car and plate shops and other shops working up structural material, owe much of their large comparative output to the careful working out of their plans in the drafting office. They owe a large proportion of it, however, to the development of the machinery used in this class of work and also to the arrangement of their shops for economical working.

We still have the small shop where one punch with shear attachment is almost the entire plant. Perhaps the rivets are driven by hand, it may be by power of some kind. It is true also that work can be turned out as cheaply here as in a shop with all the modern improved machinery.

The old center punch remains and it will be many years before it is superceded. But its usefulness as a single punch has been improved upon. By means of a spacing attachment duplicates are punched more rapidly and without the aid of templets, without also the marking off necessary in single punch work. Gusset plates, clips, channels, miscellaneous and odd pieces all find their way to center punches after being laid off or marked off.

In shops doing special work of any amount it is universally the custom to adapt punches to this special work. In beam shops, punches, at one stroke, will punch 5, 8 or 10 or more holes in the end of a beam. In car shops, a press will be rigged up to punch numerous holes in a piece, for instance, a bolster or truck frame. In plate shops one end of a plate will be punched in 40 or 50 or even 60 places at one stroke, or both edges of the plate will be punched in one run through a rack punch with an even spacing. A bridge or structural shop will punch all column flanges and webs, all girders, flanges and webs (excepting of course any odd ones which creep in) on a multiple punch with an automatic spacing arrangement.

The four flange angles of a girder or column are usually punched in one run through the machine; all the holes in the web are punched by a second run through the machine. It is often that the stiffener and fillers on girders are punched on this tool each stiffener requiring one stroke to finish it.

In another class of machines there has been rapid progress, namely riveters. The pneumatic or air compressor riveter is used whenever it is possible to use it. Modifications of the type now exist which are hydraulic, having the pressure increased so that rivets $1\frac{1}{4}''$ in diameter can be driven cold and $2''$ rivets while hot. Pneumatic hammers are now almost entirely supplanting hand riveting. Five years ago their use was restricted; an editorial in one of the leading engineering papers in 1898 says "Except occasionally for cold riveting on light work percussion riveters are not used in shop riveting as far as our observation extended."

Multiple drills, special shears, rolls, rotary planer and side planers, straighteners and benders, calking machines, are all being improved.

The modern shop has an evident superiority over the shops of years ago in its arrangement for the work for which it is intended. There is one arrangement for the bridge plant, another for a building shop, another for a beam shop, another for a plate shop, another for a car works, but all tending to the economical working of the plant. In the last few years in this vicinity a car works, a plate shop (otherwise perhaps a boiler shop but no boilers will be manufactured) have been built, and the largest bridge plant in the world is now in process of erection. These plants have all one point in common, and that is all important machines are direct connected either to steam engines or to motors. Sometimes groups of machines are operated by motors, but shafting is reduced to a minimum. They present this difference, whereas the car plant and the plate plant are longitudinally traversed by modern electric overhead traveling cranes; the bridge shop will be traversed transversely by overhead electric trolleys. Interior columns are reduced to a minimum so that no more room than necessary will be taken up by obstructions. The relative merits of these two arrangements cannot be gone into, both having their advantages.

The whole shop system is designed to save all unnecessary labor in rehandling material. The knowledge of this arrangement and of the tools for special work enable shop drawings to be made intelligently, enable the operating department to lay out its work of getting material into the shop and to the various machines, there to bring it together for assembling, riveting, planing, boring and painting and loading for shipment.

As to erection of structural work the rigs for economical working have been and are still the traveler with false work or without for bridges. For mill building a difficulty is often experienced in using large travelers on account of the unevenness of the ground to be traveled over, this unevenness being due to machine foundations, pits, dirt thrown up for excavation, materials for foundation, etc. Ingenious methods to overcome these difficulties for particular jobs have been devised.

In the modern plant the special material, such as eye bars, pins, upset rods, rivets, castings and bolts for bridges, castings

and forgings for plate shop, axle-wheels, etc., for car work, are usually manufactured in shops devoted exclusively to one particular class of work. Thus we see the perfect bridge plant having its templet shop, its bridge department, an eye bar department, shops devoted to forgings, rivets and bolts, its machine shop, and more than likely its iron and steel foundry, storage buildings and of course a separate power house.

The car plant has its departments for shearing, for pressing, punching, axle turning and erection, its own forge, machine shop, and even its own car wheel and malleable iron foundries.

The plate plant has a department for rolling, punching and erection, with machine and forge shops.

It had been my intention to explain more fully in detail the variety in the arrangement of plants now in existence, as well as the working of some of the machinery now in use, but space and time forbid this.

I will only refer to the use within the last few years of the paint machine, especially on car work and also in painting old structures, also to the sand blast used to some extent for cleaning surfaces from rust, grease and old paint. This brings up the question of the rapid corrosion of steel work especially when exposed to fumes and other conditions, causing rapid oxidation. Various expedients have been tried to prevent corrosion, light coating of cement, etc., but there are not enough results to justify definite conclusions as to the best methods.

In the short space and time given to this subject it has been possible to hint at some of the problems which are before the structural manufacturers.

Pittsburgh is foremost in its blast furnaces and in its rolling mills, and is also first in its production of finished products of steel and iron. What the future of steel construction will be is hard to foretell. Concrete in its various forms of combination with steel has become a competitor along some lines, in foundations, short bridge spans, in tanks, in bins (grain and coal, etc.), stacks, and tile are being used in storage bins.

There is however no cause for worry. Office buildings for many years to come will be of steel. Steel cars are here to stay.

Railroads must and will replace bridges on all their lines. Electric roads have scarcely begun their development. Standpipes, stacks, furnace shells, and piping, flues, penstocks for hydraulic work, gas holders, mill building and other structures too numerous to mention are and will be of steel until we find a better substitute.

THE PRESIDENT—Gentlemen, as I mentioned at the start, we have a series of papers to-night, any one of which would fill the entire evening. There are so many things in that paper to interest us that it seems a pity that Mr. Hildner could only allude to them. It gives us a few ideas as to what we have to do if we keep up in the swim.

The subject to-night is "Modern Materials of Construction." Certainly structural steel comes under that head. The next paper will be "Nickel Steel for Structural Purposes," by Mr. R. H. Watson, of the Carnegie Steel Co. I suspect that we will know more about this subject after Mr. Watson has read his paper.

NICKEL STEEL FOR PURPOSES OF CONSTRUCTION.

BY RALPH H. WATSON.

The properties of nickel steel that recommend it as a material for construction are toughness, great tensile strength, a high elastic ratio and an ability to withstand, to a high degree, shock and repeated changes of stress. It is, in addition, of a more uniform structure than ordinary carbon steel, less subject to segregation, and less corrodible.

The property of withstanding shock is a matter of moment in materials of engineering. The present limits to the tensile strength of simple steel are the brittleness and want of reliability under shock of the higher carbon steels. The addition of nickel gives a two-fold advantage. It, first, increases the strength and ductility of a steel of given carbon content; and, second, permits the use of a higher carbon and therefore stronger steel—this on account of the greater endurance under shock that nickel imparts to the steel.

This resistance to shock is acknowledged and taken advantage of in the universal adoption of nickel steel for armor plates, where a single enormous shock must be met. Experiments have been made to test its endurance under vibratory and repeated alternating stresses. One by the U. S. Testing Bureau at Watertown, Mass., comparing nickel steel with wrought iron and steels of varying carbon, in resisting alternations of stress, is given as follows:

Under a fibre stress of 40,000 pounds per sq. in.

Wrought iron breaks after	59,000	Alternations of stress
0.15% Carbon Steel breaks after	170,000	" " "
0.25% " " " "	229,000	" " "
0.35% " " " "	317,000	" " "
0.45% " " " "	976,000	" " "
3¼% Nickel Steel Carbon .25-.30% breaks after	1,850,000	Alternations
4½% " " " " " "	2,360,000	"
5½% " " " " " "	4,370,000	"

Hadfield* quotes a record of experiments on 13-16 inch diameter nickel steel stay bolts under a stress of 1,000 pounds, one end vibrating through an amplitude of one-eighth of an inch at the rate of 500 vibrations per minute. Three specimens withstood respectively 292,420, 219,920 and 362,220 vibrations before breaking—stated to be three times as much as any stay bolt of iron previously tested.

The action of nickel steel under repeated heavy shock is illustrated in the drop tests on axles quoted later in this paper. The results of these tests are verified in modern rolling mill practice where heavy machinery parts, subject to severe shock or alternating stresses, such as blooming mill rolls, spindles and pinions are now largely made of nickel steel.

Hitherto the bulk of experiment on rolled nickel steel has been on medium steel of about 20% to 25% carbon with a nickel content of about 3%. To test the applicability of a higher carbon nickel steel for structural purposes the Carnegie Steel Company made a heat of the following composition:

Carbon	Phosphorus	Manganese	Sulphur	Nickel
0.35%	.022%	.68%	.022%	3.24%

*Proc. Inst. Civil Engineers, Vol. CXXXVIII.

This heat was rolled into plates of various gauges, angles, rounds and eye bar flats and forged into axles. A number of specimen tensile tests were made of each section and gauge, and, the results being uniform, are shown averaged in Table I.

The standard specifications for medium structural steel call for a tensile strength of 60,000 to 70,000 pounds per sq. in., an elastic limit of not less than one half the ultimate strength and an elongation in 8 inches of 22%. The average elastic limit of the nickel steel, as shown by the above table, is approximately the tensile strength and double the elastic limit of medium structural steel, while the tensile strength has been increased about 50% and the elongation diminished only 20%. The elongation in a rolled carbon steel of approximately 100,000 tensile strength has been found to be not more than 12%.

No difficulty was experienced in working these plates and shapes; specimens were sawed, sheared, punched, drilled, planed, turned, threaded and drifted.

The eye bar flats were headed and annealed at Pencoyd and pulled in full size tests. These results, together with results on a heat of lower carbon nickel steel, are given in Table II.

Specifications for large eye bars for use in long span bridges now being built are:

FULL SIZE TESTS.

Tensile Strength	58,000 pounds per sq. in.
Elastic Limit	½ Ultimate Strength
Elongation in 20 ft.	Minimum, 10%
	Average, 12%

and

Tensile Strength	58,000 pounds per sq. in.
Elastic Limit	30,000 pounds per sq. in.
Elongation in 20 ft.	12%

The elastic limit of the annealed nickel steel eye bars, as shown by the full size tests, exceeds the present specifications by over 50%. Their substitution for carbon steel eye bars would effect a saving—based upon a comparison of their elastic limits—of about one-third the weight of the eye bars. The adoption of nickel steel shapes for the other important members in bridge design would, on account of the relatively higher elastic limit in the unannealed steel, affect a still greater proportion of saving.

TABLE No. 1.

TESTS OF NICKEL STEEL STRUCTURAL SHAPES AND PLATES.

SPECIMEN CUT FROM.	Elastic Limit Lbs. Per Sq. Inch.	Ultimate Strength Lbs. Per Sq. Inch.	Per Cent. Elong. In 8 Inches.	Per Cent. Red. of Area.	Number of Tests Averaged.
$\frac{3}{4}$ in. Rolled Rounds	65780	97030	18.0	42.4	4
3 x 3 $\frac{5}{16}$ in. Angles	65610	98070	18.7	49.2	1
3 x 3 $\frac{7}{16}$ in. Angles	86790	115470	14.7	23.6	1
3$\frac{1}{2}$ x 3$\frac{1}{2}$ x $\frac{3}{8}$ in. Angles	70700	105950	16.2	37.4	1
3$\frac{1}{2}$ x 3$\frac{1}{2}$ x $\frac{1}{2}$ in. "	70220	105170	18.4	37.2	2
4 x 4 x $\frac{3}{8}$ in. "	80830	108700	14.1	39.5	2
4 x 4 x $\frac{1}{2}$ in. "	69850	100770	15.5	44.9	2
6 x 4 x $\frac{3}{8}$ in. "	67400	103550	17.3	39.9	2
6 x 6 x $\frac{3}{4}$ in. "	62080	96150	18.6	34.3	2
6 x 6 x $\frac{1}{2}$ in. "	70650	103550	18.9	39.9	2
6 x 6 x $\frac{7}{16}$ in. "	68130	106000	17.3	39.9	1
6 x 1$\frac{1}{2}$ in. Eye Bar Flats	76420	95990	20.4	45.7	3
6 x 2 in. Eye Bar Flats	73430	97550	17.8	40.7	5
$\frac{3}{8}$ in. Universal Mill Plates	64650	97500	17.3	39.3	2
$\frac{1}{2}$ in. Universal Mill Plates	70500	113600	16.6	29.2	2
$\frac{3}{4}$ in. Universal Mill Plates	63370	103550	19.4	44.0	2
Average	70400	103000	17.4	39.2	.....
ANNEALED SPECIMENS.					
6 x 1$\frac{1}{2}$ in. Eye Bar Flats	56440	82150	23.2	59.1	3
6 x 2 in. Eye Bar Flats	57470	83050	23.5	50.3	4
Average (Annealed)	56950	82600	23.35	51.1	.....

ANALYSIS: Carbon, 0.35%; Phosphorous, .022%; Manganese, 0.68%; Sulphur, .022%; Nickel, 3.24%.

TABLE No. 2.

FULL SIZED TESTS OF NICKEL STEEL EYE BARS.

ANALYSIS.	Nominal Size.	Elas. Lmt. Lbs. per Sq. Inch.	Ult. Str. Lbs. per Sq. Inch.	Elastic Ratio	Percentage Elongation. In 12 In.	In 10 Ft.	In 18 Ft.	Per Cent. Red. in Area.	Annealing Temp.
	6 x 1 in.	46300	74100	62.48	28.75	16.2	.....	49.80	1392° F.
	6 x 1 "	43100	69000	62.47	31.50	17.7	.....	49.60	1250°
Carbon	6 x 1 "	45510	70420	64.63	31.75	16.2	.....	54.80	1300°
0.21 Per Cent.....	6 x 2 "	47300	72200	65.50	30.20	16.3	.....	42.90	1517°
Manganese	6 x 2 "	46260	74290	62.27	29.60	17.4	.....	46.90	1517°
0.53 Per Cent.....	6 x 2 "	44040	68200	64.58	28.30	15.3	.....	53.10	1256°
Nickel.....	8 x 1½ "	43510	74720	58.31	31.00	14.5	.....	51.46	1292°
3.265 Per Cent.....	8 x 1½ "	43730	73620	54.40	35.17	17.1	.....	49.69	1292°
	10 x 1¼ "	44530	75410	59.05	36.66	15.1	.....	40.00	1300°
	10 x 1¼ "	46320	72920	63.52	30.33	13.7	.....	47.00	1392°
	Average	45060	72490	61.72	31.33	15.95	.....	48.525	.....
	6 x 2 in.	47820	85000	56.2	22.59	10.6	9.17	42.47	1400°
	6 x 2 "	46350	83780	55.3	29.33	12.8	10.76	52.17	1400°
Carbon.....	6 x 2 "	48580	87190	55.7	27.00	11.5	9.77	3 .80	1400°
0.35 Per Cent.....	6 x 2 "	48230	86130	55.9	22.00	11.2	9.50	41.90	1400°
Manganese	6 x 2 "	48380	86490	55.9	22.25	10.5	9.50	44.20	1400°
0.68 Per Cent.....	6 x 1½ "	49350	86240	57.2	25.17	12.0	10.44	45.75	1400°
Nickel.....	6 x 1½ "	4 820	85490	58.2	24.59	11.3	10.27	44 00	1400°
3.20 Per Cent.....	6 x 1½ "	49360	86160	57.3	23.33	9.8	8.44	42.74	1400°
	Average	48490	85810	56.5	24.53	11.2	9.73	44.00	.....

The diminished weight of the dead load of the bridge would then be an important factor for consideration; nor would it lose in rigidity or resistance to deformation under a load or shock, for in point of rigidity nickel steel excells simple steel relatively as much as in tension.

The question was raised in the discussion of a paper by Mr. Riley* before the Iron and Steel Institute as to whether "engineers and ship builders could, in dealing with composite riveted structures, such as boilers or the hulls of ships, depend upon getting rivets which would be workable and trustworthy and of which the strength would be adequate, in proportion to the high tensile strength of plates of the new material that would have to be combined." Nickel steel rivets since made and tested and to some extent applied in actual construction for boiler making have been found adequate. They are tough and fibrous, of a high shearing and tensile strength, readily worked and not unduly sensitive to careless heat treatment. No difficulty has been experienced in working the steel or obtaining tight joints.

The danger of over heating by the carelessness of forge boys must always be considered in a rivet steel. At the suggestion of the Bureau of Steam Engineering of the United States Navy, experiments were made to determine the effect of over heating on nickel steel. Tensile tests on the steel previously heated to temperatures ranging from dark red to white showed about the same percentage increase in tensile strength and decrease in ductility as met with in simple steel of a similar carbon content. Similar tests were made at Bethlehem on the shearing strength of nickel steel rivets; plates were riveted both double and single shear and for purposes of comparison, similar plates were riveted with simple steel rivets. Out of eight tests on nickel steel rivets in single shear, the plate failed in two and the rivets in six. In double shear, the plate failed in six, the rivets in two. The shearing strength of rivets, based on the tests in which the plate broke as well as on those in which the rivets sheared, was as follows:

Nickel steel rivets,	single	shear	. . . . .	85,720	pounds per sq. in.
" " "	double	"	. . . . .	90,070	" " " "
Simple " "	single	"	. . . . .	43,600	" " " "
" " "	double	"	. . . . .	46,000	" " " "

*Jour. Iron and Steel Inst., 1889, Vol. I.

The temperature of riveting did not perceptibly influence the results. Mr. White, who conducted the experiment, deduces that a $\frac{3}{4}$ inch nickel steel rivet may safely replace a 1-1-16 inch, or even a 1-$\frac{1}{8}$ inch simple steel rivet.*

The conclusions reached by the majority of investigators in regard to the relative corrodibility of nickel and carbon steel are that nickel steel offers an advantage ranging from 25% to 50% less corrosion in various corrosive liquids. The surface of the specimens compared whenever mentioned in the records of the tests, with one exception, was polished or planed. This basis of comparison is less advantageous to nickel steel than the rolled surface of the two steels. Even a slight advantage in resisting corrosion is of value in structural work, be it only enough to prevent rust until paint or other preservative is applied, for it is well known that painting steel, which has already rusted, is by no means as effectual a preservative as painting a clean surface. In those parts of a structure where renewals of preservatives is impracticable any advantage in resisting corrosion is of double importance. This suggests a use for nickel steel, to which its strength is well adapted, in the foundation steel work of heavy buildings, where the question of corrosion is now receiving serious attention.

Second in importance, only to its use in long span bridges, is the application of nickel steel to marine construction, both in boilers and the hulls of vessels. It has already been applied to boilers in the U. S. Cruiser Chicago; these have now been in service about four and a half years, and the latest report received of them was that they were in good condition, as were also the simple steel boilers put in at the same time. Their service is yet hardly long enough to test the comparative merits of the boiler plate. Nickel steel, however, would appear to offer for marine service the advantage of a less corrodible boiler, a higher possible steam pressure—from this an increased economy in steam consumption—or, with steam pressure the same, a saving in weight of boiler. This would mean thinner plates between the water and furnace, giving an increased economy in coal consump-

*Jour. Amer. Soc. Naval Engineers, Nov., 1898.

tion. As a hull material it would effect a saving in weight or an added strength of hull that would be of particular importance in torpedo boats or high grade yachts. Mr. H. A. Wiggin* estimates that in the construction of a modern battleship a saving of from 500 to 600 tons could be effected with the use of a nickel steel hull. He points to the increased efficiency that the vessel would have with this additional capacity for coal or armament.

In an extremely interesting experiment on nickel and simple steel hull plates described in his paper†, Commander J. G. Eaton, U. S. Navy, simulated as nearly as possible the effect of grounding on the hull of a vessel. Nickel and carbon steel plates riveted to angles in the manner of a ship's plate were subjected to blows from a heavy weight falling upon a three inch round face punch placed upon the plates. Under an equal number of blows both plates showed a clean apperature; "that in the carbon plate was 23.1 square inches in the clear, while the aperature in the nickel plate was but three quarters of a square inch. If these holes had been opened in a ship's bottom at a depth of 25 feet, the rate of inflow would have been 11 tons per minute in the carbon-plate and 0.36 ton in the nickel plate. The nickel plate preserved its shape, and in a remarkable degree absorbed the energy of the blows without transmitting wrecking-strains to the angles. The carbon plate was twisted and bulged, and the angles holding it were bent so badly that the whole structure was on the point of being wrecked."

Nickel steel car and locomotive axles are in use with good results. The properties essential to an axle, toughness, rigidity and resistance to fatigue or deterioration under alternating stresses are admirably met by nickel steel. In Table III. are given two averages of results of drop tests on nickel steel axles. The first is an average of forty tests from as many open-hearth nickel heats made on axles for the Pittsburg, Bessemer & Lake Erie Road, four thousand of which are now in use. The second is an average of tests on nickel steel axles of a higher carbon content forged from the experimental heat referred to at the beginning of this paper.

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*Jour. of Iron & Steel Inst., Vol. 48.
†"The Advantage of Nickel-Steel Over Ordinary Steel."

TABLE No. 3.

DROP TESTS ON NICKEL STEEL AXLES.

No. of Tests Averaged.	Analysis. Carbon, Per Cent.	Analysis. Manganese, Per Cent.	Analysis. Nickel, Per Cent.	Elastic Limit Lbs. per Sq. Inch.	Ultimate Strength Lbs. per Sq. Inch.	Elongation in 2 inches— Per Cent.	Reduction in Area— Per Cent.	Diam. of Axle at Center— Inches.	Height of Drop in Feet.	Weight of Drop in Pounds.	Defection after 1st blow— Inches.	No. of blows at which axle started to break.	No. of blows at which axle broke.	Size and Finish of Axle.
40	0.26	0.75	3.25	51130	85520	28.0	50.6	5⅜	44	1640	5½	42	67	5 x 9 in. Smooth Forged.
8	0.35	0.68	3.24	55560	97960	22.5	43.1	5⅞	43	1640	3⅜	.....	49	5⅛ x 10 in. Turned all over.

The Pennsylvania Railroad specifications for axles require the following tests:

Weight of drop—1640 pounds.

Height of drop—43 feet.

5″x9″ axles—$5\frac{3}{8}$″ at center—to stand 5 blows with a maximum deflection of $5\frac{1}{2}$inches.

$5\frac{1}{2}$″x10″ axles—$5\frac{7}{8}$″ at center—to stand 7 blows with a maximum deflection of $5\frac{1}{2}$ inches.

Nickel steel axles of .26% carbon have the rigidity of .40% carbon simple steel axles and excel them in toughness. A remarkable feature is the tenacity with which they hold together after rupture has commenced, requiring, as shown in the table, 25 blows to break after starting to crack. There is an instance of a smooth forged nickel steel axle of about the same composition withstanding ninety-five blows before starting to break and finally breaking on the one hundred and thirtieth. The endurance of the $5\frac{1}{2}$″x10″ simple steel axle of about 80,000 lbs. tensile strength, tested to destruction under similar conditions averaged thirty-three blows, with an average deflection after the first blow of 3.$\frac{5}{8}$″. The average deflection in a 5″x9″ axle of simple steel is about 5.$\frac{7}{8}$″. The high tensile nickel steel axle is more rigid than the ordinary carbon steel axle, yet requires a greater number of blows to break.

A careful series of experiments have just been completed at Perdue University to determine the relative friction of a nickel and carbon steel axle, with the following results:

(1) Nickel steel journals are found to require a longer time to wear to fit the brasses than the carbon steel.

(2) After a good fit is established nickel steel offers from 6 to 10% less friction than carbon steel.

The rigidity, hardness and uniform close grain of nickel steel makes it very well adapted for rails. Nickel steel rails were laid by the Pennsylvania R. R. on the "Horse-shoe" curve where rails experience very severe service and wear out rapidly. Mr. Joseph T. Richards, Engineer of Maintenance of Way, says of this track —"it has worn out now two or three ordinary rails and is only beginning to show the effects of the traffic, that is, the wear is hardly

enough to be considered and it should, as far as wear is concerned, outlast at least four ordinary rails. Time alone can tell how much longer it will go."

These rails were made of Bessemer Nickel steel of about .50% carbon, and 3.$\frac{1}{4}$% nickel. This first experimental lot being found too hard, recent large orders for nickel steel rails have been filled with Bessemer nickel steel of about .45% carbon, which, with the colder finishing of rails as adopted by our leading rail mills in the last few years, will produce a more elastic rail without sacrifice of the wearing qualities of the harder nickel steel.

THE PRESIDENT—Gentlemen, the paper just read, I think fulfills what I said at the beginning, that most of us would know more about the subject than we did before we heard this paper. It seems to me that within the next ten years there will be a vast change in our designs. It means metal that will stand more, that will do away with a great many of the wrecks we read about every day in the papers; it means that engineers are all doing their best to bring about perfection in engineering work.

In line with the paper on nickel steel, we have some other papers on steel forging. We have with us Mr. T. D. Lynch, of the Westinghouse Electric & Manufacturing Co., who will give us a paper on "Steel Forgings."

STEEL FORGINGS.

BY T. D. LYNCH.

The constitution of materials of construction has become a science much broader and more complicated than most men realize.

Metallurgy is a field in which all engineers are more or less interested and materials of construction are usually looked upon and discussed in technical meetings from the point of view of their use in bridges, buildings, rails, cars, boilers, etc., and known as structural material and boiler plates.

It is true that great value is not improperly placed on this class of engineering material, yet there are other uses for materi-

als that bear on different phases of physical and chemical combinations to meet given demands. No material, however, forms so great a part in our construction work, at the present time, as steel, and for the above named uses, specifications are quite complete and in the main very good. These have been standardized by the American Society for Testing Materials, and summarized in 1902 by Mr. A. L. Colby as "American Standard Specifications for Steel."

This publication does not cover all of the commercial problems we have to meet in steel; such a work is only intended to generalize, leaving special cases to be worked out by the individuals interested.

In this brief paper it is intended to note some of the characteristics of steel forgings as they have presented themselves to the writer in commercial work. This includes special forgings as well as miscellaneous shafts of common, everyday production. Special heavy forgings in which a limit has been placed on carbon and manganese, in order to meet conditions of permeability, have brought new difficulties and some anxiety to the manufacturers of high grade steel.

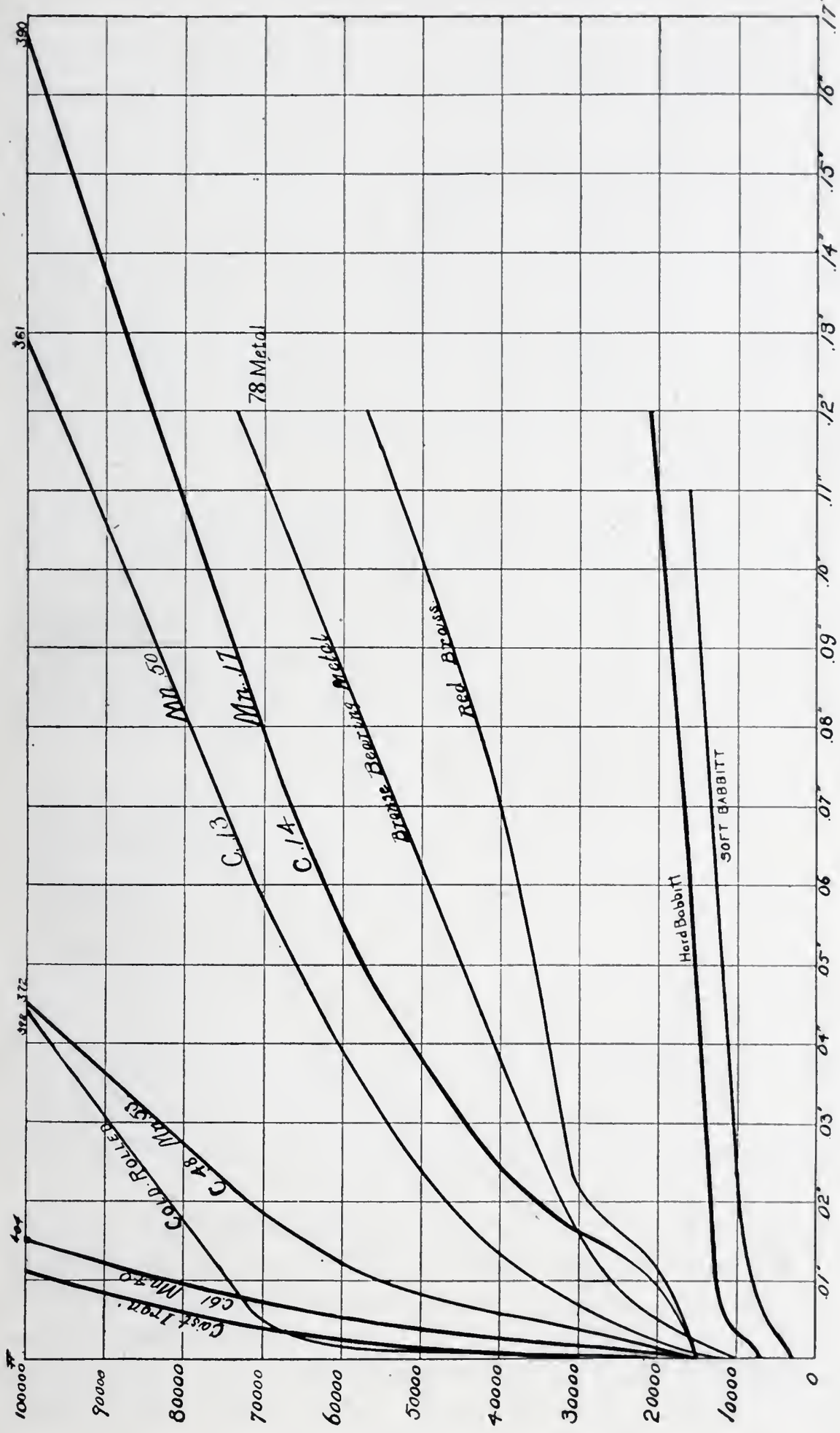
It is a recognized fact that the best forgings obtainable are fluid compressed, hydraulic forged, oil tempered, and annealed nickel steel.

The process of fluid compressing is estimated to condense the metal about 10%, forcing out the air and slag and closing up the grain.

Forging under a heavy press allows the metal to flow and gives work to the central portion of the mass.

Oil tempering is claimed by some to be a cementation or carbonizing process, while others good in authority say it is only a tempering process and its special value is due to having the liquid at a proper temperature when the steel is immersed (to exclude the air) maintaining a uniform rate of quick cooling.

In the estimation of the writer, as the result of difficulties in obtaining forgings free from surface streaks and cracks, a forging where strength is important should never be allowed to cool rapidly and in no case should such a forging be cooled except in an annealing furnace or sand bath, and thus obtain very gradual cooling and eliminate shrinkage strains.


Cast Iron.
C61 Mn 30
Cold Rolled Steel
C 18
Mn. 50
Mn. 17
C. 13
C. 14
78 Metal
Brasse Bearing Metal
Red Brass
Hard Babbitt
SOFT BABBITT
Compression in Inches.

We realize that much depends on the annealing of steel; it may be so annealed as to govern the physical qualities to a certain extent. The ultimate and elastic limit points may be raised or lowered by proper heat treatment without setting up undue strains. The temperature to which the material is raised in the furnace, and its rate of slow cooling, accounts for the size and arrangement of the crystals, which in turn alter the physical qualities. Only the manufacturers of the steel can do this successfully, as it is necessary to know both the composition and previous treatment of the metal. The slightest deviation in the temperature and rate of cooling will render the steel unsuitable for high grade service.

It is very evident to those of us who have had occasion to take large castings from the sand, and even small ones for that matter, that if the sand is removed while the metal is still above the critical temperature, shrinkage strains develop and irregular shaped castings are often broken asunder by these cooling strains, and physical tests give us unreliable results; while those properly cooled in the sand will render the material uniform in quality, easy to machine, and show good physical tests.

If this is true of castings, why is it not equally true of forgings? Slow cooling appeals to the writer to be the only means of securing uniform shrinkage. Too great care in this particular can not be given when the best results are desired.

Hollow forging has the advantage of giving more work to the center of a large body of metal.

It does not seem to be good practice to hollow forge over a mandrel less than 8″ in diameter, as the mandrel gets hot too quickly, while a mandrel 10″ to 12″ diameter is more desirable.

When properly hollow forged, a large piece of steel is much improved by the extra work done upon it.

Quite recently it has been my privilege to conduct extensive tests on hollow cylinder forgings made by Bethlehem, Midvale and Krupp, such forgings weighing from 4,000 pounds to 48,000 pounds. These cylinders were to be used under heavy strains, demanding the best material possible to get; some were nickel steel; some were carbon steel, and others were high silicon steel.

The forgings in each case had to meet given physical and magnetic conditions. A physical test was taken from near the periphery and near the bore of each forging.

In 90,000 pounds nickel steel the ultimate tensile strength and elastic limit points were about 2% higher at the bore than at the periphery, while elongation and reduction showed in some cases as much as 16% more at the periphery than at the bore. Some individual cases, however, gave practically the same results at the different locations of the test pieces. The segregations in most of the forgings seemed almost insignificant.

In carbon steel and silicon steel the physical tests were more uniform, being about the same from whatever position they were taken.

In many of these forgings white streaks were very prominent, and in a few cases cracks were found, necessitating rejections.

I am advised that nearly all of the jackets for guns for the U. S. Ordnance show more or less of these white streaks, and while they are not considered dangerous, it is certainly desirable to eliminate them, for occasionally the difference in the appearance of white streaks and that of real cracks is so slight in a forging that the most careful scrutiny is necessary.

In forgings for shafting I have traced cracks from surface to center, and sometimes extending for several feet along the shaft.

Another feature of forgings is that of hardness. This can be shown graphically by the accompanying chart. The ordinate gives the compression in inches, and the abscissa the pounds per square inch pressure applied.

Shafts low in carbon or manganese, or both, may lead to mashed keyways, bent shafts, or fatigue breaks, while high carbon or high manganese, or both, render a shaft hard to machine and subject to crystallization under constant vibration or sudden shock.

I have found the material represented by curve 372 to be an excellent steel for shafts that are subjected to hard service. This is about the quality of material in use by the P. R. R. in car axles.

A study of the chart will give relative merit in the compression value cold rolled steel No. 398; High Carbon Steel No. 404; Axle Steel No. 372; Soft Steel No. 390; Red Brass, bronze bearings and babbitt metal.

A shaft high in carbon may be softened by annealing; but if high in manganese—say .70 or .80, annealing will not soften it. For general shafting of high grade and small sizes, a steel containing .40 to .50 carbon; manganese under .50; phosphorus and sulphur under .06, treated in such a manner as to give a minimum of 80,000 lbs. tensile strength, 40,000 lbs. elastic limit, 18% elongation in 2", and a test piece 1"x½" bend 180° around a 1-½" diameter, gives good results in service.

Tests are usually taken at one-half the radial distance, either by hollow drilling or cutting from an extension of the shaft.

Forgings from high carbon steel must be carefully handled. A piece of this steel thrown on a damp floor or in a puddle of water while yet hot will temper the steel and render it hard to machine.

In small shafts varying in length and diameter up to say 6", it is, in many cases, very desirable to cut them from rounds rolled to multiple length and machined to size.

These may be tested by heats and a good uniform material assured at a minimum cost for testing.

THE PRESIDENT—Gentlemen, it is extremely interesting to have two papers dealing as they do, both with practically the same general line of work, and yet so entirely different, and each one excellent in its way. It means that we who have the privilege of hearing these papers, and seeing these charts, or getting them in the transactions, will have laid before us a working fund of knowledge that is worth the price of admission to every man. It means that we can use material more intelligently. It means that the age of guess-work is passing, and passing rapidly. It means that those who have the severest duty to meet in their work are getting to the point where they know exactly what they are doing, and it is our duty as engineers, when designing, to avail ourselves of this knowledge that is given to us.

In line with the same subject, we will call on Mr. Jas. H. Baker, Vice-President and General Manager of the Jas. H. Baker Mfg. Co., who is one of our new members, but one of our old citizens, to read us his paper on "Some Characteristics of Good Forging."

SOME CHARACTERISTICS OF GOOD FORGINGS AND SOME THINGS TO AVOID.

BY JAMES H. BAKER.

This paper is for the benefit of young men. It is somewhat embarrassing to talk before the assembly of intelligence before me, which is far greater than that of the individual. But to talk about what is needed in forgings is easier than to obtain the results desired. I mention only an instance or two in illustration of each of the points I name. I omit some points because they have been treated by others here to-night.

First, we take for granted that the proper material should be chosen. This should be determined by the service required on the one hand, and the suitability of the metal for forging the article with ease and economy. An article of one form might be easily made from metal inclining to red shortness and be very serviceable when cold. On the other hand, the form might require so much abrupt bending, etc., that we might need metal more easily worked even if it was not quite so strong when cold.

That wrought iron is better suited for some forgings, and steel for others there is no doubt. For instance, iron chain, especially that for cranes and hoisting, is superior to steel both in reliability and wearing qualities. But for common purposes steel chain is lower priced. For such articles as pull bars with holes near the ends, steel is superior because of the tendency of iron to split out from the holes owing to its fibrous structure. If iron is used for such work the fibre should either be knotted or placed around the holes.

At times the question of what relation to certain parts of the article certain parts of the metal should be placed, becomes important. For instance, I believe when forging die blocks from

ingots, the ingots, or blocks from them should be quartered and so forged as to bring the outside parts of the ingot to the face of the die. And there is a right and wrong way to place a wrought iron bar in relation to strains in some articles because of the way the "pile" was rolled.

"It will be seen that it is easier to break a bar edgewise made from such a pile than to do so flatwise. I have known instances in which this difference was the difference between failure and success."

It is perhaps needless to say that the question whether to use the press or hammer is of importance, especially on heavy forgings. The hammer, particularly if it is light in comparison to the work, will operate mostly on the surface, thus elongating the outside portions, and dragging the central part with them. On the other hand, the slow working press will drive the center the fastest.

"Whether you drive the outer portions faster or the inner part faster is to my mind a case of 'Six of one and half a dozen of the other' so far as damage is concerned."

Therefore, theoretically there is a proper sized hammer or press head, driven at a proper speed for any given size to be forged. For some kinds of work roll forging will produce a superior product economically.

Forging is not generally considered a matter of engineering, but it becomes so in designing forgings. Of course the first requisite is to have them answer their purpose, while at the same time forms should be provided such as can be cheaply and uniformly well made. The knowledge of the forgeman should go hand in hand with the engineer.

Often there is a great excess of metal put into a forging, because it is thought to simplify the making, when if reasonable forging talent had been brought to bear in designing it would have been found that the lighter article could have been as easily made as the heavier one. For instance, I show here a brake rod end for a railway car brakes, which weighs 7 pounds, and also one which weighs $2\frac{3}{4}$ pounds. Anyone can see that the heavier one has no advantage whatever over the lighter one, since they are to be attached to the same sized rod.

Now taking, say, 800,000 cars which have been equipped with air brakes in recent years with an average of 10 to each car, the saving in this one item, small as it is individually, would have been 16,000 tons, to say nothing of hauling this dead load. In other words, this item at $30 a ton, would have meant a saving of $480,000. This is all the more remarkable because this form was adopted as a standard by engineers. Thus standards are made and used right along with defects, perhaps as to usefulness, and certainly as to economy.

Forgings should be free from "cold shuts" in bends, upsets, etc. In such articles as eye bars, hoisting hooks, etc., these are dangerous, because they may be caused by the method of bending or upsetting, and then closed in forging, so as not to be seen, thus causing the piece to break very unexpectedly.

One of the troubles with electric welding has been a lack of pervading work after welding. But too much work after welding is bad. Tests on 2" Chain showed that a gang of men working by the day and slowly welding forty links per day did not produce as good chain as another gang working by the piece and making seventy links per day. Remember the old adage, "strike while the iron is hot," and do not forget the other one, "the devil gets the man who works cold iron."

Where wrought iron is used the fibre should, as far as possible, be unbroken in all bends, offsets, etc. Where wrot. iron forgings are to be finished nicely, the slag should be washed out of the surface and the forging made so near to size that a very slight cut need be used in milling in order that a clean silvery surface may be produced.

"To cut much below the surface in such cases will show black streaks of slag."

Drop forgings are often called for when the work could be shaped cheaply in a press with cast iron dies. Needless pains are taken to forge to exact size in parts where it is expensive to do so. Many blue prints are sent out on which it would be well to note "castings finish," and save cost. Again there are forgings on which fine forging finish is desirable.

"The mandril I here show was made for piercing billets for seamless tubes, and shows a highly polished surface made by a

hammer, producing a very dense and hard skin and it is therefore better fitted for such work than a machined piece."

In making up a design for an article that could be in most part made easily of a given sized bar, we should try to avoid any deviation which would make it necessary to use a heavier bar. For example, a flat bar cannot be easily forged into a round bar of equal sectional area.

"I have lately seen a blue print of a piece of work about 6 feet long which could be made very cheaply from a rolled bar, were it not for one point that cannot be made from the proper sized bar needed for the other parts. And yet large quantities of these forgings are being used at probably twice the cost, simply because of this one point in this piece, to my mind a needless one."

Many of these sayings may seem like platitudes, but I assure you we are often meeting the need for some of these hints.

If anything I have said will help the young engineer, I shall be pleased.

JAS. H. BAKER.

THE PRESIDENT—Mr. Baker, as you have already judged for yourselves, speaks of what he knows. I know a little about the matter myself, and I can only agree with him that too many engineers, in designing forgings, utterly overlook the forging end of it, that is the blacksmithing part of it. They uselessly and needlessly increase the cost and weight, when a little knowledge of practical forging would be extremely advantageous in every way.

I have the pleasure of introducing to-night Mr. Dwight Goddard, of the Wyman & Gordon Co., Worcester, Mass., a gentleman whom I myself have known for 25 years. Mr. Goddard has come especially to speak on the subject of "Drop Forging."

DROP FORGING.

BY DWIGHT GODDARD.

Drop forging differs from hand forging and hammer forging, in that the shape to be formed is not obtained by slowly fashioning it with hammer, sledge, sets, fullers, flatters and other special tools, but is secured by compressing the metal in a very few

blows between two dies which have been previously wrought to the desired shape.

THE DIES.

A set of dies consists of forging dies, outside trimming dies and, if there are any holes, inside trimming dies. The forging dies are the most important item. A pair of dies usually consists of two blocks of tool steel in which have been cut the shape to be forged. There are often two or more impressions in the same die block. On one side is an impression for breaking down or blocking out the metal, then a roughing impression that distributes the metal and approximates the shape and a finishing impression that brings the forging to exact shape and dimensions.

The shape and sequence of these impressions must be carefully considered to provide for a natural flowage of metal under hammering and to be such that the desired shape will be surely, quickly and economically formed. There must be no place short of metal, no overlapping and consequent "cold shuts" and no unnecessary blows or waste of stock. A draft of 5° to 7° from the perpendicular must be allowed to permit a free release of the forging from the die. This is especially necessary if the section is such that an unusually quick chilling of the stock would cause the forging in shrinking to grip the die.

It requires a specially trained machinist known as a "die sinker" to make these dies. He must have experience and knowledge as to the action of metal under hammering, must have good judgment and high skill to enable him to plan, lay out and make the impressions. He must have a ready use of tools, both hand and machine, to reduce to a minimum, the cost of the labor in making, which will be high at best. The hand tools which he uses consists of a wide range of dividers, gauges, shrink—rules, protractors, micrometers, riffles, chisels, files, and scrapers; the machine tools, die sinking machines, sensitive drills, milling machines, profilers, shapers, etc. In designing the dies, it is always best to procure, if possible, a model of the piece to be forged. Then a full sized drawing should be made showing the draft, the allowance for finish and any changes that seem necessary, to be submitted to the customer for his approval.

When the dies are about done, as far as shaping the impressions is concerned, they are clamped together and a lead cast made, as a proof of the shape. This is also sent to the customer for his approval. If satisfactory, the impressions are nicely finished to insure free release of the forging. The face of the die is cut away slightly for from ½ to 1 inch from the edges of the impression to permit the free escape of the flash, or surplus metal. A groove is also made from one end of the impression to the outside to provide room for the sprue, which enables the forger to manipulate the forging by means of the bar from which the forgings are being made. Lastly the dies are carefully hardened and tempered that they may give the maximum service.

This is a very important operation and requires great skill in accomplishing. Even hardness of the face, is essential, with no cracks or warping. By this time the dies represent great value, often hundreds of dollars. They should be capable of making from five to ten thousand forgings and the breaking of dies or the early wearing away of the edges may be a costly experience. The making of the dies is the expensive part of drop forging and forbids the making in small quantities.

The customer is usually charged only a part of the cost of making the dies, and while they are kept strictly for his use he is not permitted to remove them. In such a case the drop forger is expected to keep the dies and tools in good order and to make such repairs as are necessary and to replace them when worn out, at his own expense. The reasons for this custom are obvious. Each drop forging company has developed from this experience special methods for the designing and construction of dies, which they do not care to place at the disposal of competing companies. They are also seeking to accumulate an amount of dies that will provide them their principal business which is forging, not die making. If a customer insists on owning the dies outright he is charged the full cost of making with a reasonable charge for this engineering experience, and is expected to keep his own dies in repair.

DROP HAMMER.

One of these dies is secured on an anvil, or base, and the other is fastened in a head which is free to move up and

down in guides. The dies exactly match each other when together. To raise the head some hammers employ steam, some a belt or other device, but the most characteristic method is to use a board between two friction rolls. By bringing the rolls together the board is raised and hence the head which is fastened to it.

When the head is up, the rolls are suddenly separated which permits the board and head to freely drop. The falling weight of the head measures the force of the blow. It is under the control of the forger by his ability to limit the height to which the head is raised before being freed to drop and also, in a measure, he can check the speed of the fall by partially clamping the board. Most drop hammers are now fitted to run automatically if desired. Drop hammers are usually classified by the weight of head, viz.: 600 lbs. 1000 lbs, etc. The proportion of the weight of the head to the weight of the base is as 1 to 15 or 16. The base must rest on a deep foundation of concrete or timbers.

FURNACES.

Each drop hammer is provided with one or two small furnaces conviently located. Anthracite coal makes a satisfactory fuel except that it requires attention before shop hours to clean and bring to a proper heat and also from fifteen minutes to a half hour about every two or three hours to replenish during which time the output ceases. Natural gas and oil gas are also very satisfactory fuels, but perhaps the more common fuel is petroleum once refined. This with a good burner and properly bricked oven gives a hot, even heat that is economical, easily controlled, continuous and satisfactory. With either gas or oil there is no lost time for replenishing or cleaning.

With this form of furnace and fuel from forty to sixty pounds of steel can be raised to a forging heat with one gallon of oil. The cost of coal we have found to be about the same as oil but the greater output in a working day results in a considerable saving.

The furnace is bricked as small as possible consistant with heating the stock required. A single burner is placed at the rear of furnace above or below the stock hole, which is protected by

a baffle to turn the flame back upon itself and evenly heat all parts of the interior. While oil fuel is now commonly used it is not yet fully tested and developed. With further experience and experiment, better results will doubtless be accomplished.

FORGING.

Sufficient stock is kept in the furnace to provide a heated bar when required. If the piece to be forged is small, the breaking down, roughing and finishing impressions are all in the same die, and the forger has but to pass it quickly from one impression to another until finished, when the flash is trimmed off in a press. If the piece is small, it is allowed to cool and the flash is trimmed afterward. If the piece to be forged is large or complicated, it is often roughed out under one hammer and passed on to another to be finished.

In such cases it is often trimmed between the roughing and finishing impressions to save unnecessary hammering on the flash in finishing. For exceptionally large and difficult forgings the process is even more varied. The stock may need to be blocked out under a steam hammer. Then roughed out under a powerful hydraulic press. Then one end finished and trimmed. Then the piece turned, or perhaps bent, or twisted, and the other end finished, it may be, from the edge. Then finally the whole struck in a single die to accurately establish the dimensions. Even after that it may require some part to be drawn out under a steam hammer or bent by hand into the final shape.

Great care is required to guard against cold shuts and insufficient stock at some troublesome corner. The drop forger has not the advantage which the blacksmith possesses of changing slightly the direction or force of a blow in order to coax the metal to the place wanted, but still there are ways of changing the roughing impression, or the flash, or the fillets, so as to attain the end desired. Metal will flow under hammer blows in the direction of least resistance and coming from two parts of the same forging will often meet in the center and form a cold shut. In this case a larger fillet or a little more stock between the two will often remedy the trouble.

TRIMMING.

It is often found more economical to trim small forgings cold, in which case, if of high carbon steel, the forgings must be first annealed. For this purpose they are packed in charcoal in the usual way. Some forgings must be pickled or rattled to free them from troublesome scale.

IN GENERAL.

The process of drop forging is necessarily limited to such shapes as can be made in dies under pressure from one direction. There are limited exceptions to this as already indicated. It often happens that a slight change in the shape of the piece to be forged will seem insignificant to the customer but important to the forger. It may be impossible to forge otherwise, at least the change will reduce the cost of dies and making, a very considerable amount. The great cost of dies, trimmers and repairs of same, when borne by a small number of forgings is prohibitive, but when the number of duplicate forgings is large and the preliminary expense can be divided among thousands, the product is so even, reliable and satisfactory generally, that drop forgings are always preferred in place of hand forgings, or castings, either of steel, iron or malleable. Compared with hand forgings, drop forgings are to be preferred because of their accuracy of shape, perfect uniformity and cheapness. The slightest allowance for finish is sufficient, and parts that do not require machining need only to be polished.

Compared with steel castings, drop forgings, when possible, are to be preferred, because of their entire freedom from blow holes, and consequent greater reliability. Many small pieces, in quantity, can be made more economically than steel castings and some larger pieces when not too complicated, if wanted in sufficient numbers, can also compete in cost. Drop forgings because of their greater strength and perfect uniformity are better than malleable castings. The costs averaging about the same in quantity.

Drop forgings in quantity can also compete with cold punchings for such purposes as spur gear blanks, rings and flat shapes. The labor cost is about the same but the greater economy of stock

is a saving. The process of drop forging improves the quality of the steel because the severity of the blows necessary to force the metal into the dies, is so great that it thoroughly permeates the stock. In hand forging different heats and different mechanical treatment of different parts of the same forgings, cause them to possess widely different physical properties. In drop forging the treatment is thorough and equal. The smaller forgings are refined sufficiently by hammering, but larger forgings such as crank shafts, boiler clamps, etc., are greatly improved by annealing. In general any material that can be forged can be drop forged.

Low carbon steel being preferred to higher because it can be heated to higher temperature for forging, which results in longer life for the dies. The process of drop forging was at first designed for small pieces but is being extended to larger and larger work.

THE PRESIDENT—There is little I could add to this exposition of the subject,—what drop forgings are, how they are made, how they should be designed. It is up to us to use them where we can.

To continue, as we have still two or three papers, we will call on Mr. Duncan MacDougal, of the Pittsburgh Steel Foundry, for his paper on "Steel Castings as used in Modern Construction."

CASTINGS IN MODERN CONSTRUCTION.

BY D. MACDOUGAL.

There has been no branch in the steel business that has come to the front in the last few years, as that of steel castings.

This is especially true in the structural work, where almost every casting formally specified was cast iron, or where built up shapes were employed. This has now been changed, and steel castings are specified in the majority of cases. In the last few years castings have been designed by engineers and made by foundries, that were thought a few years ago impossible to make.

With a view of obtaining the best results not only as to the physical strength, but also to the wearing characteristics, we are

constantly making experiments, until we have reached the stage where the modern steel foundry will make steel castings to almost any given chemical or physical specification, while a few years ago if you wanted to buy steel castings, you had to take what the foundry would give you which was generally a soft steel casting, as they would not attempt to make castings to any given specification, and the use of the casting and the wearing qualities were not taken into consideration at all.

At the present time steel castings are made by several processes, i. e., Crucible, Bessemer, Tropeneas, Acid and Basic O. H.

The Crucible and Tropeneas processes are usually employed in the making of small steel castings and railroad work where no finish is required.

The Acid O. H. Furnace permits of a more perfect control over the casting conditions than any known process. Basic O. H. castings are now being made very extensively, that process having the advantage of making low phos. product from a cheap and poor quality of scrap and pig iron, but the disadvantage of a more lively metal in casting, harder to control and greater danger of honeycomb in the casting.

In the Acid O. H. castings, the use of good stock determines the quality of the casting and in order to get good castings, free from the blow-holes and honeycomb, nothing but the best low phos. and low sul. scrap and pig iron can be used.

Steel castings should be divided into three classes.

1st Class: Very soft such as used in electrical work.

2nd Class: Medium, such as used in structural work, machinery, etc.

3rd Class: Hard, such as used in rolls, high pressure cylinders and castings that require great tensile strength.

In ordering steel castings great care should always be taken in designating finished parts, also stating for what the castings are used, thus enabling the manufacturer to better determine what grade of steel to give his customer.

The most important factor in making steel castings is to properly head and gate them so that castings will be properly fed while the main body is solidifying. This is done with large heads

above the casting and are of such a size that the metal will flow from the head down into the casting and supply the gap made by the shrinkage of steel.

Castings of complicated shapes are very likely to be internally strained by the forces at work in cooling; part will be in tension and part in compression, and in designing the most important factor in intricate shapes is to have as near as possible a uniform thickness of metal. I have seen several instances where castings have broken after being out of the sand several days, awaiting the process of cleaning, owing to bad design.

This important point should bring steel manufacturers and engineers closer together than they now are, as I am satisfied time and expense could be saved by the designer consulting the manufacturer on intricate shapes, and many of the shapes we are called upon to produce, could be more satisfactorily made.

Castings as a rule, except special cases when made from Acid O. H. steel, need not be annealed, as almost any specification asked for to-day can be had without annealing. As we well know, the annealing process relieves the strains and while it increases the elongation and reduction of area, it reduces the tensile strength and elastic limit. To prove this, I made the following test of bars taken from the same heat of steel:

Test No. 1. Annealed gives us an elastic limit of 38,400 lbs., tensile strength, 70,750 lbs., reduction of area, 27 per cent., and elongation 32 per cent. in 2". Bending bar, 180 degrees.

Test No. 2. Unannealed gives us an elastic limit of 39,050 lbs., tensile strength, 73,950, reduction of area, 19 per cent., and elongation 28 per cent. in 2". Bending bar, 145 degrees.

Thus you see that the unannealed test bar will answer for almost any specification asked for in the general work.

These tests bars were taken from driving wheels cast in one of the regular heats made at the Pittsburg Steel Foundry, Glassport. The chemical analysis of heat was .26 Carbon, .67 Manganese, .23 Silicon, .045 Phos. and .027 Sul.

THE PRESIDENT—It is very probable that most of the engineers who have had occasion to design steel castings have become acquainted with some of the facts that have been given to us to-

night, in a way they did not like. For my part I have, and if we had known a few of the little points we have heard just now, it would have saved us some mortification, and perhaps some dollars.

The next paper is of a somewhat different character. It is on "Properties of Wire Used in Telephone Work," by Mr. R. A. L. Snyder, of the C. D. & P. T. Co.

Mr. Snyder is unfortunately absent to-night, and if it is the sentiment of those present, we will print his paper in full in the proceedings, and not take the time to read it to-night.

PROPERTIES OF WIRE USED IN TELEPHONE WORK.

BY R. A. L. SNYDER.

Telephone Companies use seven kinds of wire with widely different characteristic properties:

1st. Hard Drawn Copper. 2nd. Soft Drawn Copper. 3rd. Seven Wire Messenger Strand. 4th. Seven Wire Guy Strand. 5th. Galvanized Iron Wire. 6th. Galvanized Plow Steel Wire. 7th. German Silver Wire.

To these might be added: 8th. Aluminum Wire. 9th. Phono-electric Wire. 10th. Phosphor Bronze Wire. 11th. Bimetallic Wire.

When the American Bell Telephone Company first started in business they used galvanized iron wire, for all their outside lines. It was found, before long, that iron wire did not last and had a rather high ohmic resistance. Besides the high ohmic resistance the resistance of the line increased very materially to the pulsating current used in transmitting speech. This resistance to a pulsating current increased with the frequency. At a frequency of about 400 per second, (not high for telephone currents), the resistance of a No. 2 iron wire increased over six times its ohmic resistance.

Now, the resistance of hard drawn copper for pulsating currents, is but little greater than its ohmic resistance. For long distance Telephone lines No. 6 B. & S. hard drawn copper is used. The resistance of this wire is .403 ohms per 1,000 feet. The ohmic

resistance of the same sized galvanized iron wire would be 2.32 ohms per 1,000 feet, or six times as great. Now, if the ohmic resistance of iron wire is six times that of copper and the resistance of iron wire increases three or four times as much with pulsating currents, it is apparent that hard drawn copper is twenty to thirty times a better conductor than galvanized iron wire of the same size. The American Bell Telephone Company soon recognized this, but copper wire at that time had a very low tensile strength, and was not suitable for line work; so they sent one of their men (Mr. Doolittle), to the wire mills of the Bridgeport Brass Company for the purpose of securing a copper wire that would have a high tensile strength. After considerable experimenting he succeeded in producing a hard drawn copper wire with a reliable tensile strength of 60,000 lbs. per square inch. The conductivity of this wire was 97% of that of pure copper. This wire has to be handled very carefully as a slight scratch on its surface greatly reduces its tensile strength. This hard drawn copper deteriorates slowly while galvanized iron wire rusts very rapidly in our smoky cities. The advent of hard drawn copper practically ended the use of galvanized iron wire for telephone lines.

Soft drawn copper wire is used by the Telephone Companies for conductors, where high tensile strength is not required. It is used because of its high conductivity. With the exception of silver, it is the best known conductor of electricity.

Messenger Strand is used for supporting lead covered cables. It is made of the best hard tempered plow steel. The strand consists of 7 No. 11 B. W. G. galvanize wires twisted together. The completed strand must be able to stand a tensile strength test of 17,000 lbs, without breaking, which is equal to 218,000 lbs. per square inch. Our specifications call for each wire to be one of continuous length, free from factory joints. It is impossible to join two pieces of this wire together and make the joint as strong as the rest of the wire. We used to have agreat deal of trouble with strand breaking at these joints; so we specified that it should be free from them. This limits the commercial length to about 1,500 feet per piece. We used to buy it in mile lengths.

Guy strand used for guying poles, is made of an inferior grade of steel. It is composed of seven No. 11 B. W. G. gal-

vanized steel wires twisted together. The completed strand must be able to stand a strain of 6,000 lbs. without breaking, which is equal to a tensile strength of 92,000 lbs. per square inch. It is very much more flexible and easily handled than the messenger strand.

Galvanized Iron Wire is used only for lightning rods on poles and for supporting some few light okonite cable. No. 6 B. W. C. is the size generally used.

Galvanized Plow Steel Wire is used for river crossings. Here the tensile strength is the prime property required, and the conductivity is a secondary consideration. The tensile strength of this wire is about 230,000 lbs. per square inch. The electrical resistance is from 20 to 30 times greater for telephone currents than the resistance of hard drawn copper.

German Silver Wire is used in switchboard circuits for shunts and cutting down current. It offers a great resistance to the passage of an electric current.

Aluminum Wire has been tried for telephone circuits. At present the Telephone Company has an aluminum line working between Pittsburg and New Kensington. The line was first put up in December 1899, of a solid No. 10 B. & S. gauge wire. The wire proved very treacherous and not uniform. It appeared to crystallize and break at certain points. The maintenance of this line was six times as great as for a similar copper line. The No. 10 wire was replaced after nine months' use by a strand of three No. 12 wires twisted together. A test of the No. 10 wire showed its tensile strength to be 513 lbs. The No. 10 aluminum wire was used to replace a No. 12 hard drawn copper wire whose tensile strength was 560 lbs. The aluminum wire will only stand 20 twists in six inches while a copper wire will stand 40 before breaking. The elongation of aluminum is much greater than that of copper. The coefficient of expansion is 1-3 greater than that of copper. This is a disadvantage. The three wire strand is doing fairly well. Our greatest objection to it is that during every wind storm it becomes crossed with parallel copper lines. With a little more improvement in drawing and a reduction in price the stranded aluminum wire will have a share in telephone work.

Phono-electric Wire is something new which is being pushed as a wire to be used through mountain districts. The claims for it are that it has about 33% greater tensile strength than that of hard drawn copper and that it is not so treacherous. The conductivity is 39% of that of wire.

Phosphor Bronze Wire is sometimes used for river crossings. It has about 33% greater tensile strength than that of hard drawn copper. It has 26% the conductivity of copper wire.

Bi-metallic Wire has not quite the tensile strength of phosphor bronze wire but it is a little over twice as good a conductor. It consists of a copper wire with a steel core.

The goal for which telephone wire manufacturers are striving is to produce an alloy of cheap metals that will not deteriorate and at the same time have great conductivity and tensile strength.

THE PRESIDENT—The last paper is on "Cold Rolled Steel," another,—I won't say just new development in metal work,—but one that is of increasing importance, by Mr. J. J. Crane, of the Westinghouse Electric and Manufacturing Co.

COLD ROLLED STEEL.

BY J. J. CRANE.

The paper I have prepared for this evening may seem to some of little importance for a gathering of engineers, "The Process of Cold Rolling Steel." For example let us take watch spring as it is received from the hot mill. This should be as thin as possible, but it does not seem practicable to have it rolled under .058, or No. 17 guage, in lengths 35 to 40 feet. This steel should not have been more than .002 variation from center to edge of a strip $3\frac{1}{8}$ inches wide of high carbon steel. Watch spring is very hard and springy when received from the hot mill and must be annealed before rolling. After annealing, it is placed in a vat of sulphuric acid to remove the scale or oxide. Then to bosh or tub of boiling water with lime or sal soda to remove any acid on the steel from pickling.

It is now ready for the rolls for the first roughening. These rolls are of chilled iron or forged steel 9 inches in diameter, 14

inch face, turned in the lathe, as near the diameter as possible, then placed in the grinding machine, which gives a high polish. Great care must be taken in grinding and not to force the wheel and allow it to run until it clears the roll, which takes from 5 to 6 hours for each roll.

ROLLING OF WATCH SPRING.

This steel is passed through the rolls four times and reduced from No. 17 guage to .045, provided it does not vary too much from center to edge. If it does not, you must reduce the variation in the first rolling to make it a success. If this variation is not reduced, it will cause the strip to split through the center or crack on the edges. This may be overcome by shaping the rolls, which is done by using a stick and fine emery. Much time is required scouring and shaping.

After the first rolling, the steel is annealed for the second time, then returned to the rolls. This rolling reduces it to .025 and annealed again for the third time. Then rolled again. This reduces it to .010. Annealed for the last time and finished .006, which leaves the steel soft enough to form the springs. The rolling hardens the steel which makes it necessary to anneal it so often. It is then carefully inspected and guaged, for not more than $\frac{1}{2}$ thousand from center to edge of strip is allowed, then taken to the slitting machine and both edges are trimmed.

Shoe shank, hack saw blades, clock spring and corset steel is put through the same process.

FOR STAMPING DRAWING AND NICKLE PLATING.

Soft O. H. basic and Bessemer steel is used. This is ordered different guages according to the size to be finished in cold mill. This steel is received in coils 65 to 75 feet long and 2″ to 6″ wide. The rolling of this grade of steel does not require the labor and expense connected with watch spring. The majority of it is soft enough for rolling when received. It may be reduced 2 or 3 or 4 guages, according to the size required. Some coils will measure 700 to 800 feet when finished. It is then inspected, annealed, tested and ready for shipment. The test given dead soft steel is the bending. It must bend over on itself with the grain and across the grain and show no fracture.

I will enumerate some of the articles this steel is used for —keys, locks, pants buttons, sewing machine parts, suspender buckles, door knobs, skate plates, hinges, tubing, rims for cycles and automobiles, also many other articles too numerous to mention.

Cold rolling is more accurate to guage free from oxide, soft and ductile, and by far superior to hot rolled steel for drawing and stamping.

We also have what we call half hard. This is reduced down to within .004 or .005 of finished size, then annealed and re-rolled, inspected, tested to bend to angle 45° with the grain. The steel for nickle plating is reduced about 4 guages and the roller must be very careful that his rolls are in good condition, for any sand holes or flaws in the rolls will leave the impression on the steel.

There is considerable trouble with seams in this grade of steel, and I have known as high as 50% to be thrown in scrap. This is no fault of the cold rolling. These seams are in the steel when received and cold rolling exposes them very plainly and renders it unfit for nickle plating.

Key steel does not require any annealing and is reduced about 2 or 3 guages. This leaves it soft enough to punch and a fairly good surface. This is then cut into 6 foot strips and shipped.

PICKLING.

A few words in regard to pickling. This is the placing of steel in a bath of diluted acid to remove the scale. It is necessary in the operation of cold rolling steel, and it may be hastened by having the acid hot. The steel should not be left in the acid any longer than is necessary to remove the scale. If left in the acid too long, it becomes worthless and rotten. The writer thinks that the only way to remove the acid is by placing it in a furnace and baking. The temperature of this furnace should be from 400° to 500° F. This does not discolor the surface. In pickling thin strips care must be taken and not have the acid too hot or in many cases, it will blister the steel. Some of the orders call for a lime finish. This is done by placing the steel in diluted acid and when removed, placed in a vat of boiling water and from this vat to the lime vat, then dried thoroughly in a furnace to prevent

it from rusting and shipped with the lime on. This coating of lime makes it easy on dies for stamping and drawing.

ANNEALING.

Great care must be taken with the annealing of cold roll steel and in order to make it a success the furnace must be well adapted with a fire box in the side, the flame passing out over the bridge wall and should always hang to the top, passing down the other side through the checker work and down under the bottom into chimney flue on opposite side into the stack. All cold roll steel is annealed in round or square boxes, the round for coils and the square for strips. In packing the steel in the boxes a space of about 1″ is allowed for cast iron turnings, which are placed all around the steel. This prevents the air coming in contact with the steel. It is then placed in the furnace. The time required for annealing depends on the amount and grade of steel. A pan of 8,000 or 10,000 pounds of basic or O. H. would take from 8 to 10 hours and drawn out when the required temperature is reached. As soon as the heat is drawn out of the furnace a gas pipe ½″ diameter is inserted in the lid. The gas is now turned on and forces any air that comes in contact with the steel while cooling. There is not a great quantity of gas consumed in this operation because the expanding gas in pans makes a back pressure. Steel annealed in this manner will be bright and ductile when removed from the pans—show no oxidation. This is a brief outline of the general working of cold rolled steel.

The President—This paper again illustrates how much there is of which we know nothing. We know of cold rolled steel, but we did not have a definite knowledge of the intricate processes required to produce what is known to us so commonly. We have had now seven papers, one after another in such rapid rotation, and all so interesting that I am afraid we are rather lost. At the same time the papers are open for discussion. I will not start on any particular one, but allow the discussion to take its own course. If there are any questions to be asked on any paper, please start the ball rolling.

Mr. J. L. Klindworth—I would like to ask the authors who had papers on steel castings and drop forging whether they

have made any attempts on steam pipe flanges in their respective lines.

MR. GODDARD—I think our Mr. Wyman at one time became interested in that question. I do not know just what stopped it. The superintendent told me one day that it was too big a proposition for him.

MR. KLINDWORTH—It seems to be the large sizes that make the trouble.

A MEMBER—What do you call a large size?

MR. KLINDWORTH—Fifteen to sixteen inches.

A MEMBER—We are making them of that size by the hundreds to-day.

MR. MACDOUGAL—We are making them very successfully with the thin end up, and cutting them off afterward.

MR. WHITED—I would like to ask the gentleman who read the paper on nickel steel if he will tell us something about the difference in cost, or rather in price, between the nickel steel and carbon steel.

MR. WATSON—The cost of nickel steel depends first upon the cost of nickel, which is approximately 35 cents per pound. The extra cost would probably be from $10 to $12 per ton for every per cent. of nickel in the steel. Against this you have the nickel steel scrap. The nickel can be almost entirely recovered from the scrap. In steel rails, which wear out comparatively quickly, this is of course an important item.

THE PRESIDENT—It seems to me there is more than that to be looked at in the nickel steel,—that is the fact that if the nickel steel will stand so much more, there is no reason why a structure cannot be made so much lighter that it will offset the extra cost. It is like aluminum, which at $2 per pound was a laboratory curiosity, but to-day it is anything but a curiosity.

A MEMBER—Do you suppose you could make lighter rails with nickel steel?

MR. WATSON—The nickel steel rails that are being rolled now for the Pennsylvania Railroad Co. are 85 pound and 100 pound sections. Of course nickel steel has superior rigidity, but against this is that the 100 pound section has just that much

more head to wear, and will last that much longer after being laid down.

THE PRESIDENT—Mr. Hildner, what effect do you think that would have?

MR. HILDNER—I would rather leave that to some of the older members.

MR. WHITED—Mr. President, another thing that has often come up in connection with nickel steel is the supply of nickel. There is a good deal to be said on both sides of that question.

MR. WATSON—I think the supply is equal to the demand. I know it used to be some time ago that the nickel mines were not particularly profitable on account of lack of demand for nickel. I do not know but what that condition still exists.

MR. KLINDWORTH—To change the subject, I would like to ask Mr. MacDougal to give us a few points on steel castings. He made it appear that a great deal of money could be saved by a proper design regarding castings with cross ribs, etc.

MR. MACDOUGAL—I could not do that without naming particular instance. You will find that the engineer, in designing, will give a very heavy outside and a very light casting of rib. On an order we had for a wheel, one of the things we had to do was to cut down the weight 10 per cent. We told the man we could do that. We took off 18 per cent., and I claim had a stronger casting than before.

MR. G. E. FLANNIGAN—Mr. President, I remember some years ago seeing a design for a beam that was designed without regard to shrinkage. It was a T section, with a heavy flange and a thin rib. The shape of it was so abnormal that really it was weaker by condition of the rib. The rib became the tension member. It had to pass through an opening which was T shaped itself. In speaking of designs I would like to emphasize Mr. Baker's remarks. When I was in touch with both the machine shop man, the foundry man, and the blacksmith I always seemed to think I could make designs all right without consulting the foundry man and the machinist, but on work of a complicated character I talked to the blacksmith, and took him into consultation before making the work; otherwise, the result was when the forgings were made they did not look like the drawing.

MR. WAGGONER—Mr. Watson's paper on nickel steel covers the field well in general. As I do not think it is the intention of his paper to cover the use of nickel steel in engine construction, I would venture to ask what would be the result on an oil hardened nickel steel crank pin or shaft of an engine in case the said pin or shaft should get what would be called "smoking hot" and then cooled off with water? Whether it would not destroy the good qualities of oil hardening and in that case would it be advisable to harden while in service?

As we all know, the running parts of machinery are liable to become very hot for several reasons such as overload, neglect, stoppage of lubricant, etc., and on that account it has been our practice at one of the large rolling mills of the Carnegie Steel Co. in Pittsburg to use the nickel steel forgings without hardening after finishing. Our experiences with nickel steel under the conditions spoken of has been highly gratifying; of course at first we had our own troubles, but they have been overcome. One of the first difficulties experienced a few years ago was in getting what was wanted in the nickel steel, such as the carbon contents, etc.; cases have been when the forge would send anything in stock irrespective of our specifications and forgings which were not suitable for the duty intended.

It is now our practice to replace all important members of the very large engines and locomotives, when failing from the effects of heavy service, such as crank pins, piston rods and connecting rods, with nickel steel containing 0.25 to 0.30 per cent. carbon and 3 to 4 per cent. nickel. The results have been all that could be desired. We have some large engines of the older types which were designed for low pressures of 80 to 90 pounds per square inch boiler pressure which are now working under a pressure of 130 pounds per square inch, and it is possible to get this increased service with the use of nickel steel forgings for crank pins, connecting rods, etc. This speaks well for the increased strength of nickel steel parts of the same dimensions as the previous parts of ordinary steel and we have found in our experience with nickel steel all the good qualities which Mr. Watson has spoken of in his paper.

MR. FLANNIGAN—Mr. President, before anybody else leaves the room, I would like to say one word. I would like the Society

to compliment the members who have written papers for them, and in reading over the list, whether we read the program from first to last, or last to first, or begin in the middle and read both ways, I think we will find that the authors have gone to a great deal of trouble to prepare their papers, and they deserve a vote of thanks from the Society. I therefore make a motion that the Society tender each one our thanks.

THE PRESIDENT—It was with fear and trembling that I received the news when Prof. Kintner told me we had eight papers. I told him we could not handle eight papers, but he said that he had written to this one and that one, and not getting any reply, had written to a number, and finally they all decided to give him papers, and when they all came in, each one seemed so good that he could not forego the pleasure of having all these papers, so he took the bull by the horns, and notified each one that they would have to keep within certain limits. Each one was long enough to keep us the whole evening, and yet they were so well handled that we got a good idea of each subject.

MR. FLANNIGAN—Before you put the motion, I want to include the paper that was not read. From what we know of Mr. Snyder, we know it is a good one.

Motion carried.

MR. KLINDWORTH—Before we close, I would like to make this announcement, that the members interested in the Mechanical Section notice there was no paper announced for the June meeting. I think I have succeeded in getting a paper telling us something on the testing of wire rope, and Mr. Diescher will give us something on the designing of rope wheels and drums, and will give a good many notes on hoisting ropes, etc.

THE PRESIDENT—Gentlemen, all of us have to do with hoist-apparatus in one way or another, and most of us have run against wire rope difficulties, and any light we can get on that subject is worth considering.

Remember that about three-fourths of the members have signified that they wished to be considered members of both the Structural and Mechanical Sections.

On motion the Society adjourned at 10:30 o'clock.

CHARLES W. RIDINGER.
Secretary.

STRUCTURAL SECTION.

A meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held in the Society's hall, 410 Penn Ave., Pittsburg, May 26, 1903.

Meeting was called to order at 8:30 P. M. Fourteen members and visitors present.

Members of standing committees announced as follows:

(a) Committee on Timber Construction:
Marshall W. Brown, Chairman;
Willis Whited.

(b) Committee on Masonry Construction:
H. C. Gould, Chairman;
A. G. Shaw.

(c) Committee on Rolling Mill Practice:
S. B. Ely, Chairman;
R. H. Stevens.

(d) Committee on Railroad Bridge Construction:
E. K. Morse, Chairman;
E. A. Amaden.

(e) Committee on Highway and Trolley Bridge Construction:
V. R. Covell, Chairman;
C. M. Conady.

(f) Committee on Mill Building Construction:
L. F. W. Hildner, Chairman;
P. Bryan.

(g) Committee on Office Building Construction:
Charles Worthington, Chairman;
G. H. Barbour,
W. H. Baltzell.

(h) Committee on Concrete-Steel Construction:
W. G. Wilkins, Chairman;
W. A. Smith.

(i) Committee on Shop Practice or Methods:
J. H. Thompson, Chairman;
T. D. Lynch.

Discussion of the subject for the evening: "Office Building Construction," was participated in by Charles Worthington, F. S. Rice, George H. Randall and others.

Subject selected for next meeting "Building Stones of Western Pennsylvania."

Section adjourned at 9:40 P. M.

WILLIS WHITED, *Sec.*

POWER PLANT DESIGN.

BY R. W. STOVEL.

If we agree that the best power plant to supply certain definite power requirements is that one which at the end of a term of years, say ten, has supplied these requirements for least expense including first cost, operation, supplies, maintenance, repairs, renewals, delays and present value; we can divide the problem into two parts.

The first part is the determination of the requirements and the second part is to find the ultimately cheapest way of supplying them.

The requirements are determined by the owner, assisted by the engineer, who should see that no steps in the manufacture which can be economically performed by power are omitted, that the most suitable forms of power are considered for the different processes, that the work is arranged or routed properly and above all that adequate allowances are made for growth.

The requirements being determined the different methods of power application should be considered and decision made whether it is more economical to install isolated power units or to transmit steam from a central boiler plant with steam engines located at different points throughout the area to be supplied or to install a central generating plant and transmit some form of electrical energy and develop power where required by electrical motors. If the latter method is found more suitable, the form of electrical energy must be determined, whether direct current at some voltage or whether alternating current shall be used, and if the latter, what frequency will be used, at what voltage we will generate, at what voltage we will transmit and to what voltage we will transform down for use at the motor terminals.

These questions should all be solved by their reduction to dollars and cents, nor is it a question of which motor or system is the most efficient considered individually but which equipment

gives the greatest return on the investment, all expenses being taken into account.

It will, in general, be found more economical to install a central power plant with some form of power transmission on account of the saving in attendance, in delivery of supplies, and in making the average load on the plant more uniform.

For our present purpose which is to briefly call your attention to some of the details found in the power plants of this district we will assume that these questions and the question as to what form of machine will drive the generators; whether water turbines, gas engines, reciprocating steam engines or steam turbines, have been decided in favor of a central generating station with generators driven by reciprocating steam engines.

Curves showing the sum of the power requirements for different hours of the day and for different periods of the year should be plotted, from an inspection of which suitable commercial sizes can be selected for the generating units, care being taken to select sizes so those running will operate at nearly full load rating for different conditions of the load. As many of the units as possible should be the same size, to allow interchange of working units, to facilitate repairs and to prevent delays due to part of the plant being incapacitated.

By assuming proper efficiency for the generators and engines combined 70% to 85%, and suitable performance for the driving engines from 13 to 30 pounds of steam per indicated horse power hour these output curves should now be reduced to boiler horse power, that is to 30 pounds of steam per hour. To these the steam required for auxilaries and for other than generating purposes should be added. From inspection of these new curves suitable commercial sizes of boilers from 100 to 650 horse power can be selected and additional ones added to allow the proper proportion, from 5% to 10% depending on the feed water, to be out of service for cleaning.

With the size and number of the generators, engines and boilers determined we can form an approximate idea of the space required for the power house and can proceed with its construction.

In the selection of a location for the plant the following points are among those which should be considered:

The location should be as near as possible to the power centre of the area to be supplied so that the loss in transmission is a minimum. It should be such that it will be possible to extend and increase the capacity of the plant. It should be convenient for the delivery of fuel and other supplies, and situated where suitable feed water and condensing water, unless a cooling tower is to be used, can be obtained. The power house should be detached from inflammable structures, likely to cause damage by fire and from buildings where any vibration is objectionable. The power house itself should be of fire proof construction throughout and particular attention given to getting good foundations and as much natural light as possible.

It should be remembered that a power plant is not to be judged by its condition when just completed but by the continuity and efficiency with which it supplies the required power, and and the arrangement of all the main features and details should be such that the failure of any single piece of apparatus will not cause a temporary shut down.

Not only must the engines, boilers and generators receive proper thought but the connecting links, the auxiliary apparatus, the piping, wiring, etc., must be carefully planned if the plant is to give economical and uninterrupted supply.

We will now pass to the consideration of the different pieces of apparatus usually found in local power plants though, of course, whether these are or are not installed in each case depends on the requirements and on whether a consideration of all the factors involved shows their installation to be a good investment.

Such a plant as we have assumed will consist of the following parts:

Receiving of coal from point of supply, its storage and feeding to boilers; the removal and disposal of ashes; obtaining feed water, perhaps from river or well, heating it and putting it into the boilers, obtaining the necessary draft for burning the fuel; the generation of steam, its distribution to main engines and aux-

ilaries in a dry state; the disposal of exhaust steam by condensation or to free exhaust, operation of main engines and the generation of current; conducting current from generators to switchboard; manipulation and control of the current and its supply to service.

BOILERS.

Boilers are usually designed to have from 10 to 12 square feet of heating surface per horse power and there is greater difference in efficiency among boilers of one type owing to design and arrangement than between the different types properly proportioned, the water tube boiler being considered the safest and easiest steaming type.

The type of boilers whether water tube or fire tube and if the latter whether return tubular, locomotive or vertical, having been decided, attention must be given to the setting. The foundations should be of the best and the drums supported from steel frame work independent of the brick setting. The furnace and generally most of the internal walls should be lined with fire brick. Pockets to allow for expansion of bridge and flame walls should be left in the side walls. Header courses should be frequent throughout the setting. Woven wire is sometimes used as a bond throughout the walls to prevent their cracking. Proper room should be left for drawing tubes and arrangements made for disposal of the blow-off. It is well to use two valves on each blow-off, one to act as a guard in case the other is worn or clogs. Check valves are used in some cases on the steam pipe from each boiler so that should accident happen to one boiler the remaining boilers will not blow out through the damaged one. The artificial light should be arranged so that the water columns are readily seen.

Proper support for the smoke flue should be provided. Where uniform steam pressure is desired, as where the load is mostly engines, a pressure regulator should be adapted to the main flue damper. Devices for maintaining uniform water level in the boiler may be installed for convenience, but should not be trusted to do away with constant attention from the fireman.

COAL AND ASHES.

The method of handling the coal from cars or barges to the stoker hoppers, of arranging suitable storage, and of handling ashes from ash pit back to the cars or barges, should be planned ahead so that the necessary arrangements can be incorporated in the construction of the building. The various methods of doing this were described very fully at the last meeting of this Section. In the larger plants the coal handling machinery is separate from that handling ashes, the ashes in this case being dropped from ash pits into cars which are elevated and dumped into the ash storage. In smaller plants, however, it is often desired to combine part of the machinery and use the coal elevator for hoisting ashes, delivering ashes to a storage bin over coal siding by an adjustable gate in the discharge chutes. Owing to the cutting action of the ashes on the machinery this should only be done when it is understood that the depreciation of the apparatus handling ashes will be very rapid. In arranging this machinery easy access should be provided to all moving parts and particularly to the engine or motor driving it. Some protective link such as a current fuse or a wooden key is desirable to prevent wreckage due to clogging by large lumps of coal. Wooden timbers should not be used in blocking up the gears on account of warping due to rapid drying out in boiler room. The whole apparatus should be well cased in to prevent the flying of dirt.

STOKERS.

This point has also been under discussion before this Section recently and need not be gone into here. They can in general be shown to be a profitable investment even in this district of cheap coal when more than one fireman is necessary. When properly designed they should feed coal to the furnace at a desired uniform rate with minimum labor and be so arranged that the volatile gases given off the entering coal shall have perpect combustion before passing from the furnace.

FEED WATER.

Emergency arrangements can generally be made for fuel supply but it is not usually easy to make quick emergency arrange-

ments for an extra feed water supply and therefore great care should be given to the installation of feed water apparatus.

As to the source of feed water, Nature has not been very generous to us in this district. The supply of sulphuric acid and sulphate of lime seems more than adequate, but good water is scarce. This is being overcome by treating the water either before it goes to the heater, in the heaters or in the boilers themselves. If the plant is large enough or if the expense is not prohibitive the first method is preferable.

Almost all the waters of this district can be satisfactorily treated and either one of two results obtained. Either the resulting water contains a soft sludge which settles in the boilers and has to be washed out or else the water contains salts in solution, which owing to concentration in the boilers will cause foaming unless blowing out is performed regularly. In stationary boilers the latter evil is probably the lesser. We will, however, leave this subject to the tender mercies of the Chemical Section.

If possible two independent sources of water supply should be provided for feed pump suction. No power plant is too small to have two independent methods of forcing the water into the boilers. In small plants a feed pump relayed by an injector which should be operated from time to time to see that it is in order, is satisfactory, while in larger plants two or more feed pumps should be installed. These pumps should be very strong, usually of the solid plunger, outside packed type with easily accessible water valves, of very liberal capacity and equiped with water relief valves. The feed water piping should be heavy and have extra heavy fittings forming, if possible, a loop so any section can be cut out without stopping supply to other boilers. If the impurities in the water are likely to act on iron the feed piping, particularly that part conveying hot water, should be of brass. This piping should be supported independently of the boiler settings to avoid trouble due to settling of walls.

FEED WATER HEATERS.

Feed water is heated before it enters the boilers and the consequent economy of 1% of fuel for every 10 to 12 degrees heated gained by three methods. First by a heater sometimes called a

primary heater installed between the engines and condensers, heat to the temperature of steam at the vacuum used being available. Second by a heater called a secondary heater, installed in the steam passage to free exhause the temperature here being 212 degrees. Third by a heater called an economizer, installed in the passage way of the gases leaving the boiler and which usually run from 400 to 600 degrees, where the feed water can be heated to about 300 degrees F.

The first two heaters may be either of the steam coil or water coil type with copper, brass, or charcoal iron tubes, or coils, if the feed water is such that a deposit is at all likely in the heaters, these should be of the straight water tube type with removable heads to permit cleaning.

Closed feed water heaters used in the free exhaust line are generally designed to have 1-3 of a square foot of heating surface per horse power rating, but if particular results are wanted the heater should be more carefully designed with regard to material of tubes and velocity of water in them.

The second class of heaters or those in the free exhaust may also be of the open type where the exhaust steam comes in contact with the feed water, and in some cases these heaters are used as purifiers, part of the scale forming matter settling out owing to the water temperature being raised. As exhaust steam from reciprocating engines always contains more or less oil, the open heater should not be used, especially in connection with water tube boilers, without proper consideration of the troubles which may be caused by this oil getting into the boilers.

The third class of feed water heaters or economizers consist of vertical water tubes, joined by headers, mounted in the flue carrying the hot gases from the boilers and have scrapers which keep the outsides of the tubes free from the constant deposit of soot. It is always desirable to arrange a second passage way from boilers to stack so that the gases may be by-passed around the economizers to allow for repairs and proper allowance must be made in stack for reduced temperature of gases and increased friction of passage way.

DRAFT.

Draft may be obtained by three methods: chimneys, mechanically driven fans including draft or mechanically driven fans forcing a draft. The latter method is not much used, the selection being generally between the two former methods and should be based on a consideration of first cost, operation, and repairs, allowing for the possibilities of increasing the capacity during emergency and the more perfect control of the induced draft method.

Owing to the cheapness of fuel in this district economizers and condensers are not usually found in the moderate sized plants and owing to the nature of the fuel which by comparison does not require a very great amount of draft for proper combustion, the usual method of obtaining draft is by brick chimneys or by brick lined steel stacks. The height of a stack should be based on the required amount of draft for proper combustion of the fuel, which varies with nature of the fuel used, allowance being made for loss of draft due to friction of gases in stack, flues, boilers and grates. In many cases, owing to local conditions as to adjacent hills or high structures, the stack has to be put higher than estimated by the above method. The height being determined, the stack must have sufficient area to carry away the total amount of gases at a velocity which will be caused by the draft obtained.

PUMPS.

Pumps for general water supply may be either reciprocating, centrifugal or rotary. The reciprocating pumps may be either steam or power driven. Usually the nature of the service will determine the class of pump, the steam pump being best adapted where a constant water pressure is to be maintained, as a valve actuated by the water pressure may be put in the steam line to pump and thus control the admission of steam. It should be remembered that the simple steam pump takes from 90 to 125 pounds of steam per horse power hour and the compound steam pump takes from 60 to 80, as against about 20 pounds per horse power hour in the generating engines, so that where the exhaust steam from the pumps cannot be used for heating and where fuel is dear the power pump is generally more

economical in consumption of power though not so readily controlled.

Where the head and volume are constant the centrifugal pump, direct connected to a motor, makes a very suitable arrangement on account of its simplicity, cheap first cost and small floor space. Centrifugal pumps designed to fit conditions can be made to have an efficiency of about 60%, and while this is not equal to the efficiency of power pumps the centrifugal pump will in some cases on account of first cost, maintenance and room occupied, be found the cheapest arrangement.

The pumps should be located so that the suction lift will not, under worst conditions, be more than 18 to 20 feet, suction lines for reciprocating pumps should have an air chamber near the pump and by locating this so the momentum of the water acts directly against the air cushion instead of rushing past it, all water shocks may be avoided. Both suction and discharge pipes should be designed so the loss by friction is not too large. This, of course, depends on length of pipe, but for ordinary conditions a water velocity of 300 feet per minute gives good results. Easy arrangements for priming should be made and a water relief valve put in the discharge line to prevent excessive water pressures.

CONDENSERS.

Condensers by causing a vacuum on the exhaust side of a piston of an engine allow the steam to expand through a greater range, that is, to reach a lower thermal limit and consequently save from 15 to 25 per cent. of the steam required to develop the same work. Depending then on the cost of fuel, the cost of condensers, their maintenance, the extra piping involved and the cost of power for the circulating water, the condenser is, or is not, a paying investment. Where exhaust steam can be used for heating purposes the gain by use of condensers is reduced, while on the other hand, if the feed water supply is very bad or costly, the water of condensation may, by being properly freed from oil, be reused and a large saving in boiler repairs and cost of feed water be made.

Condensers are of three types: the surface, the jet, and the siphon or barometric jet. In the former, the condensing water

does not mix with the water of condensation, the exhaust steam and condensation being drawn over a series of tubes by a pump discharging to waste or to a hot well while cooling water is being circulated through the tubes by another pump. In the jet condenser the cooling water and exhaust steam are mixed in a chamber and are drawn out by a pump. This method cannot be used when it is desired to use the heated product for feed supply unless the supply of cooling water is also good for feed purposes.

The siphon condenser is similar to the jet except that it has a vertical discharge pipe over 34 feet in height, so that the condensation dropping down creates a vacuum in the head and no pump is needed.

ENGINE ROOM.

Even in the moderate sized plants the installation of a hand power crane pays for itself during erection, while in larger plants an electric crane, capable of lifting the heaviest piece of machinery, is usually installed. Sufficient room for good passage way between engines, after all piping is in place, should be allowed and the apparatus set so there is room to dismantle the engine or generator for repairs. Galleries around and between the engines should be designed with the method of operation in view and arranged to save as much labor as possible in engine attendance. Oiling arrangements should be planned, the different oils being piped to the points of use and kept under pressure by a pump or by compressed air, then drained by pipes to the filtering tanks.

If compressed air is available, this should be piped to points throughout the engine room so the more inaccessible parts of the machinery may be cleaned by its use.

PIPING.

The piping is a very prominent factor in the satisfactory life of a power plant. Leaky joints, water in engine cylinders, water hammers and shocks can be avoided by properly designed piping. Some of the more common methods of piping are:

1. Cast iron bell and spigot pipe with leaded joints mostly used for water and gas lines which are buried in the ground and seldom found inside the power plant.

2. Wrought iron and steel pipe of different weights with cast iron screwed fittings of corresponding weights, generally used for all purposes in the smaller sizes.

3. Wrought iron pipe with cast iron flanges and cast iron flanged fittings of different strengths, used in the larger sizes and where it is probable the piping will have to be frequently disconnected.

4. Cast iron flanged pipe is used for exhaust steam and light pressure work, being in the larger sizes cheaper than wrought iron pipe.

5. Riveted sheet steel pipe is used for light pressure work such as exhaust steam and blowing air.

STEAM PIPING.

The pipe sizes should be such that they will carry the needed amount of steam without undue loss of pressure. Average velocities of the steam in the pipes for reciprocating engine leads, being from 2,000 to 4,000 feet per minute and higher velocities, can be used where rate of flow is uniform.

The steam piping is usually of wrought iron or steel pipe with flanges and flanged fittings bolted together with either rubber or metal gaskets between the flanges. The flanges are generally screwed on the pipe, but there are several other ways of attaching them, the best undoubtedly being that of welding steel flanges to the pipe. There are in general two classes of flanged fittings known as "Standard Weight" and "Extra Heavy Weight," the former used up to 100 or 125 pounds pressure and the latter from that up to 200 pounds.

The dimensions of these fittings, the number of bolts, the diameter of bolt circle and so on for the different sizes are likely to vary with the maker and always form a very troublesome detail in the piping work. Two standards known as "A. S. M. E." for standard weight fittings and the "Manufacturers" for extra heavy fittings, have been adopted by the Manufactuers' Association and are coming into general use. I would suggest that in buying apparatus, vexing details and delays may be avoided by specifying and insisting that all flanges are according to these standards.

The fact that iron expands with heat seems to be frequently forgotten when steam piping is being laid out and long runs of straight pipe are sometimes fastened by rigid fittings to fixed pieces of apparatus.

This expansion and contraction can be readily calculated and should be properly cared for by bends or offsets of sufficient length for the deflection required, otherwise unnecessary and often dangerous strains are caused in fittings and valves, ultimately causing leaks.

These steam pipes should be supported in such a manner as to allow this expansion to take place and should be anchored in a way which will cause the expansion to take place in the direction desired.

All water pockets in main steam lines should be avoided, for which reason gate valves are to be preferred in steam mains rather than globe valves.

The water of condensation and in suspension in steam lines must be removed and is done by the use of steam traps or a Holly steam loop which automatically returns the water to the boilers without the aid of moving apparatus. This cleaning of the steam lines is greatly aided by intelligent arrangement of pipes and fittings based on the appreciation of the fact that the steam and water are moving at the rate of three to five thousand feet a minute.

From the location in which we sometimes see pipes it might be thought these could be put anywhere. This idea is, however, likely to prove expensive before the pipe has outlived its usefulness. All steam pipes should be placed where every fitting can be inspected from time to time and where all the pipe can be covered.

The subject of pipe covering has recently received some attention, the general result of which has been the statement that even with cheap coal the installation of a high grade of covering is a good investment. The covering on steam pipes should of course be non-inflammable and material that will not char with time. Among other substances carbonate of magnesia and asbestos are frequently used.

WIRING.

This, too, is a detail worthy of some thought. Current conductors are of three kinds:

1. The conductor covered with a series of braids saturated with a preservative compound known as "Weatherproof" which is used for overhead outside work.

2. The conductor insulated with rubber and protected with braid used for work inside buildings and in conduit in dry places.

3. The conductor insulated with rubber or paper and sheathed with lead, this for use in damp or wet places and in conduit in damp places. These conductors should be supported in such a manner that the insulation will not be damaged by the supporting device and should be properly protected from chances of mechanical injury. As the larger lead covered cables cannot be turned around a sharp corner, proper space for the wiring between generators and switchboard and from switchboard to service should be provided in advance.

Passing to the consideration of the completed plant, a moderate sized one in this district might be briefly described as follows:

Building 100 x 70 x 30 feet high. Brick with steel columns.

Six 250 H. P. Horizontal water tube boilers equiped with stokers actuated by two 6 H. P. steam engines. Steam pressure 150 pounds.

Coal and ash bucket elevator with a capacity of 30 tons an hour, driven by a 10 H. P. motor.

Coal conveyor of same capacity, driven by a 7½ H. P. motor.

Coal storage of 300 tons above front of boilers, feeding by spouts to stoker hoppers.

Brick stack 8′ diameter, 135 feet above the grates, fuel being "slack."

Two 9x5x10 pressure pattern feed pumps with 4″ feed line.

One 1,000 H. P. feed water heater with straight brass water tubes.

One 10 ton hand power crane in engine room.

Five 250 H. P. compound non-condensing engines running at 280 R. P. M. direct connected to 150 K. W., 240 volt, D. C. generators.

Two compound steam compound air compressors, each with a capacity of 1,000 cubic feet of free air per minute to 100 pounds.

Piping—Steam; wrought iron pipe with extra heavy flanged fittings, 8″ delivery from boilers, 10″ main header, 6″ leads to engines, 4″ leads to compressors. Exhaust 16″ main of cast iron with 8″ wrought iron branches from each engine and compressor. Steam piping drained by a Holly loop, this plant being run non-condensing, as part of the year exhaust steam is used for heating.

As to the larger central station practice we gather the following from Mr. Wells' paper before the Association of Edison Illuminating Companies comparing the five largest stations in New York.

They have a capacity of from 15,000 to 40,000 rated boiler horse power in units of from 265 to 650 H. P. The stacks vary from 200 to 350 feet in height above lower grates, in some cases fans being used to assist the stacks. The coal handling machinery has a capacity of from 125 to 180 tons per hour and the majority use motors for driving this machinery. They have a coal storage of 1-3 to ½ ton per rated boiler horse power. All the boilers are of the horizontal water tube type and all but half the boilers in one plant have stokers. The working steam pressure varies from 150 to 175 pounds per square inch.

In four plants the feed pumps are steam driven, having compound steam cylinders, the fifth plant having motor driven power pumps.

Three of these plants have economizers, three having primary heaters, that is heaters in the steam line to condensers and three have heaters in the free exhaust lines. The engines are all compound reciprocating steam engines of from 4,500 to 8,000 nominal H. P. with 60″ stroke running at 75 R. P. M.

Three plants have jet condensers and the balance the surface type. The generators are all of the three phase alternate current type generating at from 6,600 to 11,000 volts.

In conclusion, your attention is again called to the fact that the power plant of to-day is a commercial proposition, an investment on which dividends are expected and that these dividends are not necessarily greatest when some pieces of the apparatus have reached their highest stage of mechanical or thermal efficiency. Mr. Booth calls attention to this in his article in the Engineering Magazine for April where he says "The end and aim of the engineer is primarily to reach his purpose without unnecessary expense." The end of a power plant is to supply its requirements and to supply them all the time.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and thirty-sixth regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's House, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, June 16th, 1903, at 8.10 o'clock, First Vice-President James M. Camp in the chair, and ninety-two members and visitors present.

The minutes of the previous meeting were read and approved.

The Board of Directors reported that they had passed favorably on the following applications for membership and present same to the Society for action.

CHAS. A. BACON, - Engineer of Construction, - Pittsburg, Construction Co., Pittsburg, Pa. — { J. W. Walker, Edw. Garrick, Percy Nicholls.

R. E. CECIL, - Draughtsman, - Riter-Conley Mfg. Co. b., 6205 Alder St., Pittsburg, Pa. — { L. F. W. Hildner, F. S. Rice, S. F. Barth.

CLARENCE J. COON, - Charge of Party, - Wm. G. Wilkins. h., 6309 Marchand St., Pittsburg, Pa. — { N. F. Hopkins, W. T. Wallace, C. W. Ridinger.

GEO. DONALD, - Draughtsman, - Riter-Conley Mfg. Co. h., 23 Butler St., Millvale Station, Allegheny, Pa. — { L. F. W. Hildner, F. S. Rice, Z. H. Sikes.

FRANK C. EMERY, - Foreman, - Westinghouse Machine Co. h., 7326 Kelley St., Pittsburg, Pa. — { H. L. Barton, W. P. Flint, E. S. McClelland.

MELVIN A. GILBERT, - Draftsman, - Riter-Conley Mfg. Co. h., 41 Center Ave., Emsworth, Pa. — { L. F. W. Hildner, H. M. Wilson, F. S. Rice.

WM. S. GORDON, - Engineering Department, - National Tube Co. 3515 Fifth Ave., Pittsburg, Pa. — { E. D. Hancock, H. G. Wardale, C. W. Ridinger.

C. A. GRAHAM, - Draftsman, - { F. L. Irwin, F. B. Bissell, E. T. Parker.
Standard Steel Car Co.
h., 27 Beyane Ave., Bellevue, Pa.

AUGOSTUS B. GRANGE, - Purchasing Dept. - { R. A. McKinney, S. B. Ely, F. W. Kennedy.
American Sheet Steel Co.
h., 4732 Wallingford St., Pittsburg, Pa.

RUSH N. HOSLER, - Mining Engineer, - { E. W. Hess, A. E. Hess, W. G. Wilkins.
Morrisdale Coal Co.
Morrisdale Mines, Clearfield Co., Pa.

A. C. HOUGH, - Member of firm - { W. H. Smith, C. A. McClung, B. H. Taylor.
Hough & McClung, Civil Engineers,
511 Ferguson Block, Pittsburg, Pa. h., Homestead, Pa.

JOHN F. JONES, - - - Manager, - - - { Samuel Diescher, C. W. Ridinger, J. M. Camp.
M. H. Treadmell & Co., N. Y.
Peoples Savings Bank Bldg., Pittsburg, Pa.

ARTHUR LOSEY, - Draughtsman & Checker, - { Wm. Forsstrom, A. E. Gray, J. L. Klindworth.
Jones & Laughlins Steel Co.
h., 5231 Gertrude St., Pittsburg, Pa.

HARRY G. MANNING, President & Gen'l. Mgr. { F. B. Ward, John Hare, D. L Macomber.
Pennsylvania Air Brake Co.,
526 Washington Trust Bldg., Washington, Pa.

JAMES D. McLEAN, - Draftsman, - { S. F. Barth, L. F. W. Hildner, F. S. Rice,
Riter-Conley Mfg. Co.
h., 6th Street, Oakmont, Pa.

GEO. H. PROSSER, - Chief Draftsman, - { C. E. Barteau, H. C. Gould, F. H. Patton.
National Mining Co.
1224 Carnegie Bldg., Pittsburg, Pa.

H. S. SAUFORD, - Erection Engineer, - { L. F. W. Hildner, H. M. Wilson, W. C. Coffin,
Riter-Conley Mfg. Co., Pittsburg, Pa.

W. C. SEIBERT, - Asst. Chief Draughtsman, - { F. I. Ellis, T. J. Bray, Jr. E. W. Knotts.
United Engineering & Foundry Co.
h., Marshall & Kennedy Aves., Allegheny, Pa.

J. H. SMITH, - Supt. Blooming Dept. - { W. E. Prindle, C. H. Rich, G. L. Collord.
Clairton Steel Co., Clairton, Pa.

ERASTUS R. St. JOHN, Draftsman Structural Dept. { P. Brynn, G. M. Shaw, L. L. Arnold.
American Bridge Co.
h., 10 Alpha Terrace, Beatty St., Pittsburg, Pa.

CHAS. E. WADE, - President & Gen'l. Mgr. - { F. B. Ward, D. L. Macomber, John Hare.
Standard Engineering Co.
h., Ellwood City, Pa.

MR. CAMP—On looking over the list of names submitted for membership in our Society, and the names of those who proposed these candidates, I find that the new men are taking hold of this work and assisting materially to reach our goal of "One Thousand Members for 1903." This is a very encouraging sign, but the older members need not relax their efforts to the desired end on this account.

It was moved and seconded that the Secretary cast the ballot in favor of admitting the candidates listed to full membership.

MR. CAMP—At a previous meeting, there was a committee appointed to draft resolutions and report with reference to the death of one of our members, Mr. W. W. Card. This Committee has its report here, but since none of the members are present I will ask the Secretary to read the resolution.

William Warren Card was born in the town of Nelson, Madison County, New York, September 6th, 1831. His father, William J. Card, was a civil engineer and surveyor, connected with public works in Pennsylvania and Ohio, and removed with his family to Lancaster, Ohio, in 1837, where W. W. Card was educated, attending first the public schools of that place and finishing at an Academy. During his youth he assisted his father, who had been elected County Surveyor of Fairfield County, Ohio, and thus obtained a practical knowledge of the details of the surveyor's profession. After teaching school for one term, in 1850, he was given a position on the engineer corps of the Cincinnati, Wilmington & Zanesville Railway (now Cincinnati & Muskingum Valley Railroad), then in progress of construction, under the direction of E. W. Woodward, the Chief Engineer.

In 1853 Mr. Card was appointed resident engineer in charge of the eastern division of the road, which he held until the completion of the road, in March, 1856. He then accepted the position of resident engineer on the Milwaukee & Mississippi (now the C. M. & St. P. Ry), which he held until the completion of that road, in 1858. He then worked at general surveying, laying out towns and cemeteries, and in the Fall of 1859 he again entered the service of the Cincinnati, Wilmington & Zanesville Railway Company as freight bookkeeper. In the succeeding year Superin-

tendent Abbot died, and Mr. Card was chosen to fill his place, with the title of Superintendent and General Freight Agent. He remained here until May, 1864, when he was tendered the position of Superintendent of the Steubenville & Indiana Railway Company, which he held until September, 1871, when he became the General Agent of the Westinghouse Air Brake Company. In 1873 he was appointed Superintendent and Chief Engineer of the Lake Shore & Tuscarawas Railway Company (now Cleveland, Lorain & Wheeling), and built the line from Uhrichsville Junction to Wheeling. He resigned from this road in the Fall of 1879, and in the Spring of 1880 was appointed Secretary of the Westinghouse Air Brake Company, and in 1901 was elected Second Vice-President of the Company.

He was a member of the American Society of Civil Engineers, being elected in 1883.

In June, 1862, he married Miss Hattie Dinsmoor, of Delaware, Ohio, who died in April, 1886; children, Mrs. D. A. Moore, of Pittsburgh, William D. Card, Chicago, and Harry S. Card, of Zanesville, Ohio.

In May, 1900, he married Miss Maria Llewellyn, of Washington, D. C.; child, Miss Ruth Card.

While Mr. Card was well known as a railroad official, he is better known from his connection with the Westinghouse Air Brake Company. The efficiency of the air brake was first and fully demonstrated on the railroad of which Mr. Card was the Superintendent, and the historic air brake test was on a local train leaving the old Union Depot, Pittsburg, for Steubenville, on October 3, 1869. The success of the experiment completely changed the character of the railroad service in the United States, and in the world, making possible the running of trains with safety at high rates of speed, and thousands of lives have doubtless been saved by the invention of Mr. Westinghouse, which Mr. Card so ably and cordially seconded.

Mr. Card had a wide acquaintance among railroad officers, and had a remarkable memory for figures, facts and faces which enabled him to contribute much valuable matter to the railway history of the country.

Although retired from active work with the Westinghouse Air Brake Company, Mr. Card kept in close touch with the business to which he had given so much of his life, and it was in returning from his usual visit to the Wilmerding shops that he was struck and almost instantly killed opposite the gates of his residence by a trolley car, one of the modern institutions which his partner, Mr. Westinghouse, has assisted so largely in developing. Thus passed from life one of the most valued members of our Society, whose gentle manners, upright character and noble qualities had endeared him to friends and associates.

Signed,

EDW. B. TAYLOR.
CHAS. F. SCOTT.

MR. JOHNSON—I move that the resolution be accepted and spread upon the minutes of this Society. Motion carried.

MR. CAMP—I believe there is another Committee to report touching the death of another of our members, Mr. B. F. Jones.

(Mr. Diescher reads report of this Committee.)

In the death of Hon. Benjamin Franklin Jones, which occurred on May 19th, 1903, we share, with the community in which he was, for so many years, a most prominent figure, in the loss of a man conspicuous for those qualities of courage and character which have made our country what it is, and which have especially helped to bring our city to that foremost position as a manufacturing and business center which it holds to-day.

Mr. Jones was born in the town of Claysville, Washington County, Penn'a, August 8th, 1824. At the age of 19 he came to Pittsburg, and entered at once upon that active career, which has been so notable for its achievements.

He engaged in the transportation business, later entering that of iron manufacture. For more than fifty years he has been a leader in that industry and active in the great changes which have taken place, and has been most influential in bringing about that wonderful development which has made Pittsburg the greatest tonnage city in the world.

The vast industrial establishments which he created bear witness to his ability and activity.

Notwithstanding his phenomenal success, in a commercial sense, it is, after all, the man and his character in which we are most interested.

He was kindly and courteous to those about him, self-reliant and sagacious in business, inspiring those associated with him to value his judgment, while his methods were such as to win the regard and esteem of the whole community.

He was called from this life in the seventy-ninth year of his age, after many years of usefulness. As a man he was beloved by all who knew him—of a disposition genial and hearty, yet withal modest and retiring. His life was based upon high ideals. He was one of nature's noblemen," and the world is better for his having lived. Who can value the influence of such a life?

Mr. Jones has been a member of the Engineers' Society of Western Pennsylvania since 1881, and as a tribute to his worth as a man and of our regard for him as a fellow-member, we spread this memorial on our minutes.

RALPH CROAKER, JR.
SAM'L DISCHER,
E. K. MORSE.

It was moved and seconded that this report be accepted and spread upon the minutes. Motion carried.

MR. CAMP—Are there any members of the Reception Committee present? I understand the Chairman of this committee has something for Saturday night, and we should like to hear from the committee if there are any members present.

MR. BARNSLEY—I must say that the next entertainment will be somwhat later than I had originally anticipated. We had in mind an excursion for the 20th, but we have been compelled to postpone it. That being the case, the only thing I can say now is that notices will be sent out in due time to all members, giving information in regard to the proposed excursion. Possibly we may be able to arrange for a steamboat excursion on the river before September. I have had this in mind for some time and if the members give me any evidence of their desire for something of this kind, I shall be only too glad to arrange it.

MR. JOHNSON—What the Chairman of the Reception Committee would like to have is an expression from the members present as to what proportion of them would probably attend that smoker. The idea is to ascertain about what expense we could safely incur. I do not know how to get at that unless the chair would ask those present to signify their willingness to attend such a smoker, if arranged, by rising or by a vote.

MR. CAMP—The trouble is the members present only represent some ten or twelve per cent. of the total membership. I believe, however, Mr. Barnsley's idea is to give a river excursion with a smoker attachment.

MR. BARNSLEY—The idea is this: There would be a night excursion on the boat. Simply such an occasion as we can readily arrange for. The expense will be what we usually incur plus the hire of the boat. If we have it on the river instead of here, that means the expense of a boat. Before arranging definitely for such an excursion, therefore, I should like to know what the membership wishes in this connection. If the men here would signify that they do not want a smoker on the river, I would let the matter drop; but if a majority want it, I will then send out postal card notices to all members to get their ideas as to whether they could come.

MR. ENGSTROM—If I understood the chairman of the Reception Committee, all he wants is merely an assurance of the backing of those present. I therefore move that it is the sense of this meeting that we have a smoker on the river.

MR. CAMP—Those in favor of having a river excursion with smoker attachment, will please rise.

MR. BARNSLEY—I said that we would rather not make a definite statement as to the date, but it is possible we may have that excursion before the middle of July. However, if there should be a considerable proportion of our members going away by that time I would be glad to consider their wishes because, of course, the whole idea is to gratify the wishes of the largest proportion of the Society's membership possible, in all these matters. If there is any expression in regard to this matter would be glad to hear it. Otherwise we will go ahead and do he best we can.

MR. CAMP—We will now take up the regular papers for the evening: The first is a paper on "Mechanical Drawing in the Modern Drawing Room," by Mr. George H. Follows, of the Westinghouse Electric and Manufacturing Company.

MECHANICAL DRAWING IN THE MODERN DRAFTING ROOM.

BY GEORGE H. FOLLOWS.

Before I can hope to present this subject intelligently, and as I want to present it, it is necessary to come to an understanding as to what a mechanical drawing is, and also what we mean by the Modern Drafting Room.

According to the Century dictionary, "mechanical drawing" is a drawing made with the aid of instruments, as compasses, scales, rulers, etc.; or the method or art of producing such a drawing.

Now although this would seem to be the generally accepted definition, to my mind it does not nearly fill the bill. I would have mechanical drawing looked upon and taught as a "language"; a mechanical drawing becomes then the "writing of a language." This as a broad or general definition will suffice for the present; we shall arrive at something more complete and comprehensive later on. The part that instruments play in the writing of this language is analogous to the part that the typewriter plays in the writing of English. In both cases a certain amount of skill is required to manipulate the instrument, but mere mechanical skill does not make a draftsman any more than it makes a stenographer. In both cases comprehensive brain knowledge of the subject (backed by common sense) is the essential.

By a modern drafting room I mean the drafting room of a manufacturing concern as distinguished from that of a concern that simply makes things. And it must be an up-to-date manufacturing concern, one that desires its product to be in every way good, is prepared to grow to any size, and is managed by men who have already realized that the work of the drafting room, like that of the shop, must be done systematically.

There are shops even now where the drafting room is looked upon more as an irritating source of expense than anything else—"To be done away with some day, when we get things going." That, of course, is not the way we look at it. The drafting room is of as permanent use and value to the whole concern as the tool room is to the shop. And we must in the first place grant it this permanent place; it must be expected to stay and to grow with the business.

In what follows I try to show what a mechanical drawing should be in order that it may play the part it should play in the modern machine manufacturing concern.

I like to look upon drawings as "tools" so made as to be of as much and as permanent use as possible to the whole concern, and particularly to the shop. They should contain all information needed by the shop and by all offices connected with the shop, as well as such information as is needed for reference in the drafting room; but drawings should in no way *interfere* with the shop. They should clearly and unmistakably indicate required *results* but "how to get the results" should, when possible, be left to the shop, where by right it belongs.

I have seen drawings that have contained instructions like plane, bore, file, chip, turn, mill, etc. Such instructions are, as a rule, not only unnecessary but often lead to trouble. If, for example, the shop decides to grind instead of chip, or mill instead of plane, the drawing is immediately at fault; in other words wrong. There is a general principle that should always be kept in mind by the draftsman: "Drawings should be made right to stay right." This principle is many sided in its bearings; for instance, it must be remembered when naming the parts of a machine: If on the spur of the moment a material is included in the name of a piece, as "wooden ring," "fibre washer," and it is decided later (we will say a year later, after all catalogues, circulars, and printed matter in general have been issued using these names) that the ring is best made of fibre and the washer of brass, there have been introduced two very absurd errors; we have a "wooden ring" made of fibre and a "fibre washer" made of brass. And it will not be at all an easy matter to root out these mistakes.

Before going further I would like to say something (it will have to be very brief) about mechanical drawing as a language. This way of looking at it is not new, but it is made less use of than it might be.

When we think of a language, as of English, we have in mind an alphabet, words and sentences; and going further, to the written language as we find it in literature, we add, in the main, chapters and books.

Now I would like to see it recognized that there is an analogy between English as a language and mechanical drawing as a language; the analogy can be made of real practical value to the student as well as to the teacher of the subject.

Under English we have:

1. An alphabet of letters.
2. Words.
3. Sentences.
4. Chapters.
5. Books.

Under mechanical drawing we have:

1. Analogous to the alphabet of letters an alphabet of lines.
2. Analogous to words we have views.
3. Analogous to sentences groups of views representing pieces.
4. Analogous to chapters drawings (representing groups of pieces).
5. Analogous to books complete sets of drawings representing complete machines.

In the matter of uniformity, makers of books have gone a long way ahead of makers of drawings.

Take any two books and compare them; in general you will find on the back of each the name of the book, of the author, and of the publisher; inside you will come first to a title page, then a preface, then perhaps a frontispiece, and Chapter I. The page numbers are placed at the upper right and left hand corners; each chapter is divided into paragraphs and the whole book into chapters. You will find this similarity even between books of to-day printed in this country compared with books of 50 years ago printed in England.

LINES – STANDARD.

Drawing Dictionary A-1

All lines to be made with black drawing ink.

Outlines	Heavy	weight varied with discretion to suit size of part.
Hidden parts	Medium	dashes not more than $\frac{3}{32}$" long and $\frac{1}{16}$" apart.
Center lines	Thin	
Dimension lines	Thin	dashes not more than 1" long and about $\frac{1}{8}$" apart, broken to admit the dimension.
Dimension projection lines	Thin	dashes about $\frac{1}{4}$" or $\frac{1}{2}$" long, according to the total length of line.
Break lines	Medium.	
Adjacent parts	Medium	dashes not more than $\frac{1}{4}$" long.
Limiting lines	Heavy	dashes about $\frac{1}{2}$" long.
Cutting plane lines	Heavy	dashes about 1" long. use this when it is desirable not to have line cutting through view.

No shade lines to be used. The contrast between the heavy and thin lines to be sufficient to make the part represented stand out clearly.

Dec. 7, 99 Hollows

WESTINGHOUSE ELECTRIC & MFG. CO., PITTSBURG, PA. S-35567

Fig. 1.

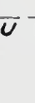
LETTERS AND FIGURES - STANDARD.

A-3.
Drawing Dictionary

TYPES OF LETTERS.

TYPE 1. A B C D E F G H I J K L M N O P Q R S T U V W X Y Z & 1/8" A to Z & 3/16"

TYPE 2. a b c d e f g h i j k l m n o p q r s t u v w x y z & 1/12" 1/24" 1/24"

The slope for both types is 3 in 8 thus: 

The oval in type 2 is shaped thus:  , and when inverted thus:  ; this oval or part of it is used in the following letters, in the manner indicated:

a b c d e g h j m n p q r

The sloping construction of A, V, W and Y, of type 1, is , not  . , not .  , not  .  , not  .

STYLES OF LETTERING.

STYLE 1. Examples: SECTION A B. PATTERN LIST.

In general this style is for titles, headings etc., and consists of capital letters 3/16" high and small letters 1/8" high, both of type 1.

STYLE 2. Example: Trim to clear bolt head.

In general this style is for everything not covered by style 1, and consists of capital letters 1/8" high of type 1, and small letters of standard height of type 2.

FIGURES.

TYPE. 0 1 2 3 4 5 6 7 8 9 5/32"

0 1 2 3 4 5 6 7 8 9 3/32"

Whole numbers: 5 10 Decimals: 0.025 0.75

Fractions: 3/4 15/16 1/4"

When there is not room for standard figures, and smaller ones have to be used, they must be made with the greatest care and as clearly as possible.

Jan. 19. 03. [signature]

WESTINGHOUSE ELECTRIC & MFG CO., PITTSBURG, PA

S.35566

Fig. 2.

SECTIONING - STANDARD.

A 0

SPACINGS  Evenly spaced, thin lines at an angle of 45° right or left, obtained with the standard section liner.

№ 1. № 2. № 3. № 4.

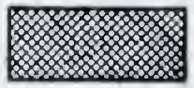
All materials, except wood, to be sectioned with ruled lines.
The spacings of the lines to be varied to suit the size of surface.

THE METALS, and all other materials except those specified below:



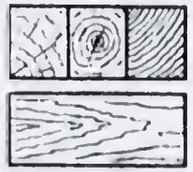
No. 1, 2, 3 or 4

BABBITT, LEAD, WAX, PARAFFIN, SULPHUR, PITCH, and all other materials that have to be melted and poured into place:



No. 1 or 2.

WOOD, whether in section or not, to be indicated by thin, wavy lines made with a fine pen:



MARBLE, GLASS, PORCELAIN, SLATE, BRICK, STONE, CEMENTS, etc..



No. 1, 2, 3 or 4.

INSULATING MATERIALS,, as fuller board, mica, rubber, fibre, asbestos, felt, paper, tape, etc.

- thickness not exceeding $\frac{1}{16}$":
- thickness exceeding $\frac{1}{16}$": 

No. 4 45° lines

12-7-99

Fig. 3.

S. 35568

DESIGNATION OF PIECES. A-20.

Drawing Dictionary.

52/3

IN GENERAL: On drawings the data contained in the designation of a piece should be given in the following order:

1 — NAME, sometimes including dimensions	7/8" Lock washer.
2 — DRAWING No., where desirable for reference	Dwg 73498.
3 — MATERIAL, using standard abbreviation	C.I.
4 — WEIGHT, in pounds	2350 lbs.
5 — FINISH, when it is not part of standard name	N.P.
6 — PIECE No.	P# 2748.
7 — DIE No.	Die # 1676.
8 — PATTERN No.	Pat. 4232
9 — QUANTITY REQUIRED	Req. 32.

EXAMPLES: Liners, # 29 sheet steel, Req. 80.
From 3/16" x 1 1/2" x 9" Hard drawn sheet copper, Req. 1.
3/4" x 6" Tap B. head S.F. & Blued, Req. 27.
7/8" Lock washer, Req. 8
Washer, P# 3471, N.P., Req. 4.
3/8" x 1 1/4" M.B. Tap B., N.P., Req. 31.

PATTERN LIST

Name	Dwg.	Mtl.	Weight	Pat	Req.
Spider	62374	C.I.	4372	K4237	1
Com. Ring	54873	C.I.	180	H3796	1

An explanatory or descriptive note added as auxiliary to the designation proper should be placed under the designation so as to leave the "quantity required" at the end of a line, where it is plainly visible after the following manner:

3/4" x 6" Tap B., Head S.F. & Blued, Req. 12.
For securing brackets to frame.

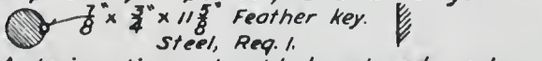
CAPITALS: The above examples indicate when a word should begin with a capital letter. In general, capitalize the first word of a designation, all abbreviations, and the word immediately following an abbreviation.

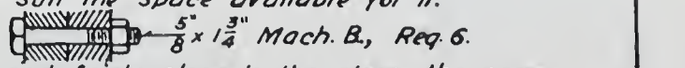
SPECIAL FEATURES: When some special finish is required on a standard or commercial article, it should not be included in the name of the piece, but should be added as a separate and distinct part of the designation. Thus, a tap bolt the head of which is to be semi-finished and blued should not be called a S.F. Tap B., but should be designated after the following manner:

3/4" x 6" Tap B., head S.F. & Blued, Req. 1.

This correct designation means that a 3/4" x 6" tap bolt, taken from stock, is to have its head semi-finished and blued, in other words that work is to be done on a standard article; whereas the incorrect term S.F. Tap B. would not only be indefinite as to meaning but would be equivalent to introducing, unofficially, a new kind of tap bolt.

ON ASSEMBLY VIEWS: A designation should be placed wherever there is clearest room for it, connected to the piece by a pointer, and arranged to suit the space available for it.

Examples:  7/8" x 3/4" x 11 5/8" Feather key. Steel, Req. 1.

 5/8" x 1 3/4" Mach. B., Req. 6.

ON DETAIL VIEWS: A designation should be placed under and fairly close to the piece, the name itself in capital letters, as a sub-title, and the specification immediately under it.

Examples:

FRONT END PLATE
4'-7 1/4" dia., W.I., Finish all over.

DISTANCE PIECE
Maple, Shellac & Polish, Req. 32.

When a piece is detailed and assembled on the same drawing the complete designation with quantity required should be given under the detail view. The reference to the piece on the assembly view should be for identifying only.

Feb. 16, 03. A.H. Bellows

WESTINGHOUSE ELECTRIC & MFG. CO., PITTSBURG, PA. S-80397

If now you compare drawings made by different men you are pretty sure to find that they are as unlike as two like things can be. From the alphabet of lines to the style of figures and letters, arrangement of views, position and style of title, and drawing number, an almost endless variety.

In any comparison between books and drawings, the books have the better of it, and the reason is not far to seek. The English language and the making of books has been studied as a language, while the making of mechanical drawings has been left to a large extent to the fancy or taste of the individual draftsman.

Not long ago I heard an engineer say, "Some people seem to find it just as difficult to convey a thought in English as some draftsmen do to convey an idea by means of a drawing." The reason is the same in both cases, insufficient knowledge of the language *as* a language.

Before an economical study can be made of a language, we must have some kind of standard dictionary. Nearly four years ago, when I first looked into the matter of a drawing system for the W. E. & M. Co., we began with the tracings; the reason for this was that it is prints from tracings that are used in the shop and business of the company, and we wanted to see results as soon as possible. The first thing determined was the alphabet of lines (Fig. 1). Then followed lettering and figures (Fig. 2), and sectioning (Fig. 3). Then came instructions regarding dimensions, dimensioning, finishes and finish marks; then the several mechanical features of a drawing, covering size of sheet, position and style of the title, drawing number, signatures, and several other features peculiar to Westinghouse drawings.

This dictionary is a twenty-page book, and being the foundation of the language, every member of the drafting room is provided with a copy.

The immediate result of this dictionary was the cutting out of individual peculiarities in the appearance of tracings made by different men. The 50,000 tracings made since the dictionary was adopted are uniform Westinghouse tracings, and all look alike. In fact, a few days after a tracing has been made, if by any chance the tracer has neglected to put his name on in blue pencil

(as is our custom) it is not at all uncommon for several men to claim it as their own work.

It is pretty generally admitted, I believe, by those of extended drafting room experience, that the modern school or college course does not properly prepare a man for actual work in the modern drafting room. Not long ago I read a letter from a young mechanical engineer in which he spoke of "mere mechanical drawing." He probably had reference to the mere making of lines—analogous to the mere thumping of the keys of the typewriter.

A draftsman cannot hope to play the part he should in the modern drafting room until he has educated himself up to his work, which is not merely the making of accurate drawings—although that is an important part of it—but the writing of a language for somebody else to read—and to read, too, without any verbal assistance from him. It must be remembered that the man in the shop is not a mind reader; I have heard it said that a draftsman *has* to be, but even that does not help the man in the shop. The language itself (and this may be taken as a fairly comprehensive definition) is one of lines, views, and group-signs, and abbreviations, notes and explanatory matter, all for the *positive* conveying of *exact* information to the shop.

A mechanical drawing should contain *all* necessary information, and nothing else; every statement, whether made by means of lines or words or combinations of lines and words, should absolutely be free from ambiguity and as clear and easy to understand as the knowledge and common-sense of the draftsman can make it.

There are in the main two sides to the draftsman's knowledge and work: First, How to convey information; second, What information to convey. The college education could easily take care of the first, if only an international standard dictionary were accepted and followed. And in connection with machine construction and design much of the second could be taken care of too, especially that very important part of design that relates to fasteners—means of securing pieces together—as bolts, screws, rivets, pins, keys, nuts, washers, etc. How to specify and convey information about these and other mechanical details and parts

that are common to many machines could be usefully taught at college, provided a recognized standard existed. In other words the college course might be made to prepare a man much more thoroughly than it does for actual work, only leaving his education to be completed in practice, instead of as very often happens now, both begun and completed.

The part of the draftsman's education that properly and necessarily belongs to the drafting room relates to special manufacturing information. In this connection it must be borne in mind that the modern drafting room should be a manufacturing concern, or factory, in itself. The distinction between a factory and a shop is generally taken to be that the work done in the factory is on a larger scale. A better distinction, I think, is that in the factory things are manufactured systematically and uniformly—not simply made; things can be manufactured in small quantities as well as in large. The modern drafting room then may turn out either many or few drawings. It is modern in the sense of being up to date if the drawings speak one good language, instead of a number of dialects, are made systematically, and are uniform as to mechanical features.

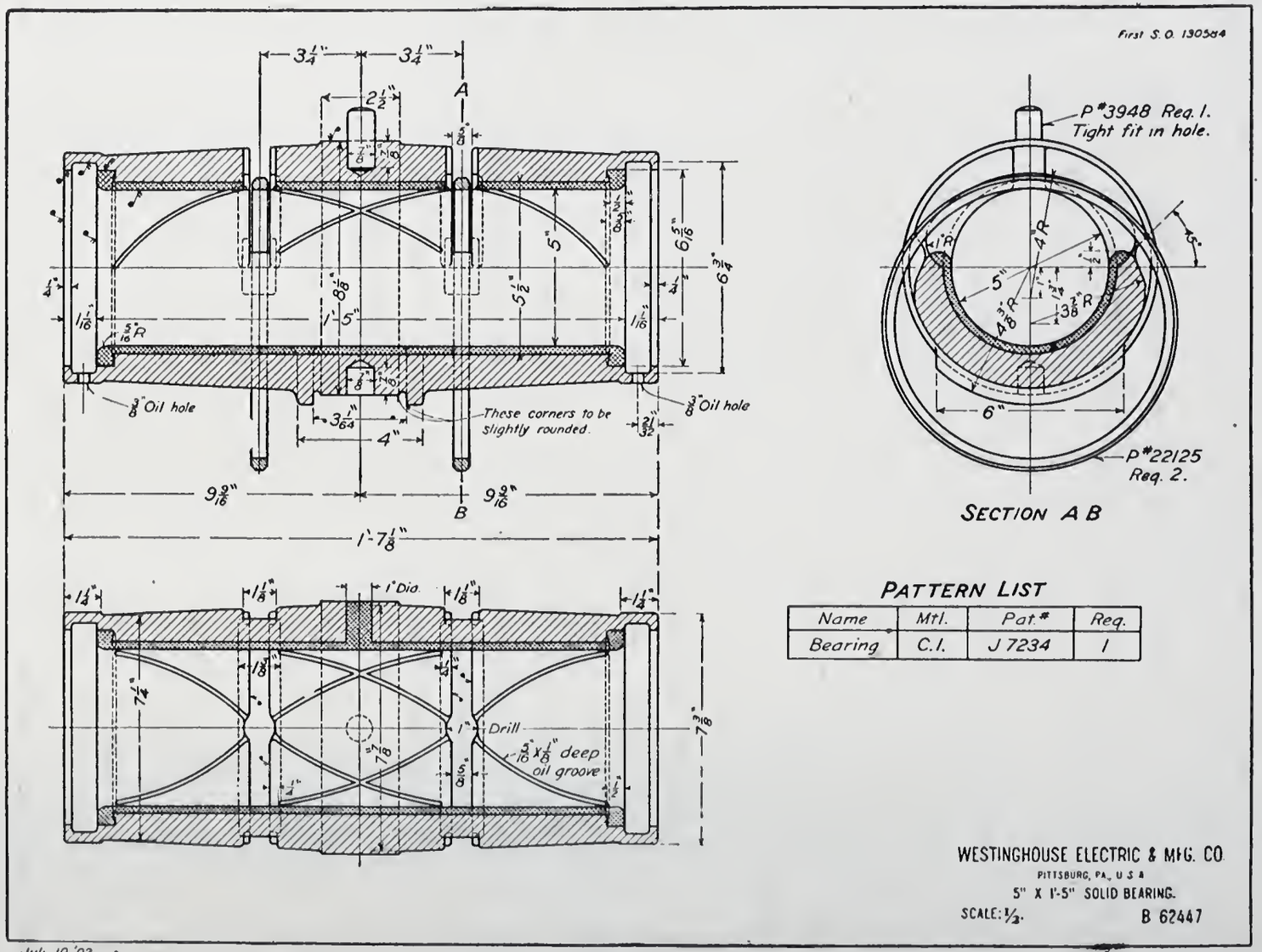
The particular drafting room in which I am interested is turning out drawings at the rate of 20,000 a year, and a constant effort is being made to get things down to a manufacturing basis —I mean as to the drawings themselves.

The drawing dictionary once established and the work of the tracers thus brought under control, we turned our attention to the designers, draftsmen and clerical force. This resulted in the formation of a separate department called the Standard Division, for keeping the drafting room posted on Westinghouse practice, preparing forms for the transaction of business, the designing of standard parts of machines, the investigation of standard methods of figuring, and the up-to-date posting of draftsmen regarding stock sizes.

The first thing taken up by the department was the matter of nomenclature, which resulted in a book of element charts and an illustrated index. In general the purpose of the element charts is to insure throughout the business of the company uniformity of nomenclature on all drawings, specifications and correspond-

SOLID BEARING: Example Layout

D-12



July 10, '02.

WESTINGHOUSE ELECTRIC & MFG. CO. PITTSBURG PA.

S-71795

D.C. E.T. GENERATORS. Gear inside frame. M 1

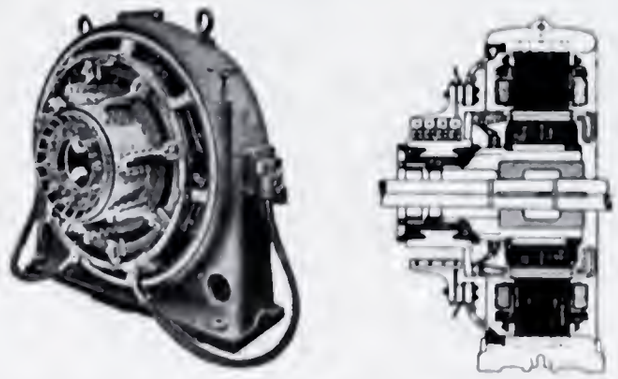
STATIONARY PART

ELEMENTS	DETAILS
FRAME	Frame castings *Poles | Pole cores, Pole shoes, Bore plates Headless set screw for locating worm shaft bushing Stud-bolt & nuts. Eye-bolts. Liners.
JACK	Jack beam & screw
BED PLATE	Bed plate casting. Guide & screws Bed plate bolts & nuts (bolts for frame & jack)
ROCKER RING	Ring castings. Stud-bolts & nuts. (when ring is in halves) Guide pieces & tap-bolts
ROCKER RING GEAR	Worm wheel segment. Tap bolts. Worm. Worm shaft Bushing. Collars. Pins *Handwheel.
BRUSH CROSS CONNECTIONS	Copper rings. Cleats. Bolts etc. *Contact plates *Terminal plates
BRUSH HOLDER BRACKET	Bracket casting. Set screw & nut Bolts for bracket, contact plate & brush holders. *Insulations, washers & washer-plates.
CARBON HOLDER	Holder. Support. Pressure plate & thumb screw Tension spring. Screw & nut. Shunts. Screw & washer. Shaft. Bush & taper pin.
CARBON	Carbon brush
TERMINAL BOARDS	Base *Contact blocks. Bolts & washers.
FIELD WINDING	Field coils. Coil hangers, bolts & washers. Leads. Strips. Bolts. Washer plates & nuts.
WIRING AROUND FRAME	Shunt, series & cable connections. Cleats & screws Bolts. Ferrules & rubber washers for attaching terminals *Terminals *Name plates
LAMP CIRCUIT	Chandelier. Lamps. Cleats. Lamp wire.

ROTATING PART

ELEMENTS.	DETAILS
ARMATURE	*Spider casting. *Punchings *Ventilating plates *Finger plates *End plates Keys
COMMUTATOR	*Commutator bars. *Commutator ring; studs, nuts & washers Insulation
ARMATURE COIL	See Elec. & Insulation Specification
ARMATURE COIL SUPPORT	Casting & screws Insulation & rivets.
ARMATURE CROSS CONNECTIONS	Cleats. Studs. Connectors. Cables.
SHAFT (Not usually furnished)	Shaft. Keys.

* Parts marked thus are detailed separately



WESTINGHOUSE ELECTRIC & MFG. CO. PITTSBURG PA.

3-42860.

Fig. 4.

ILLUSTRATED INDEX.

H 16

NAME	DESCRIPTION	STD. MTL.	ILLUSTRATION	GIVEN IN STD. DATA BOOK	S DWG. NO.	EXAMPLE DESIGNATION
Set Sc Set screw.	Square head, cup point; case hardened; U.S. Standard threads.	W.I.	Length	Diameter. Length. Thread length. Mfrs. stock sizes.	44639 44389	$\frac{3}{8}$" x $1\frac{1}{4}$" Set Sc.
Hdlss. Set Sc. Headless set screw.	Less than $\frac{1}{4}$" diameter. — Cup point, V threads.	W.I.	Length	Gauge. Thds. per inch. Length.	44391 44390	#10-32 x $\frac{3}{4}$" Hdlss. Set Sc.
	$\frac{1}{4}$" diameter and larger. — Cup point. U.S. Standard threads.	W.I.		Diameter. Length.		$\frac{3}{8}$" x $1\frac{1}{2}$" Hdlss. Set Sc.
Fil. Hd. M. Sc. Fillister head machine screw.	V. threads, blued if iron, polished if brass.	Iron or Brass	Length	Gauge. Thds. per inch. Length. Thread length. Mfrs. stock sizes.	44680 44385 44386	#14-24 x $\frac{5}{8}$" Fil. Hd. I. M. Sc.
Flat Hd. M. Sc. Flat head machine screw.	V. threads blued if iron, polished if brass.	Iron or Brass	Length	Gauge. Thds. per inch. Length. Thread length. Mfrs stock sizes.	44680 44387 44388	#10-32 x $\frac{7}{8}$" Flat Hd. B.M.Sc.
Flat Hd. Wd. Sc. Flat head wood screw.	Bright if iron, polished if brass.	Iron or Brass	Length	Gauge. Length. Thread length. Mfrs. stock sizes.	44680 44395 44396	#14-$1\frac{1}{2}$" Flat Hd. I. Wd. Sc.
Rd. Hd. Wd. Sc. Round head wood screw.	Bright if iron, polished if brass.	Iron or Brass	Length	Gauge. Length. Thread length. Mfrs. stock sizes.	44680 44393 44394	#14-$1\frac{3}{4}$" Rd. Hd. B. Wd. Sc.
Lag Sc. Lag screw	Square head, gimlet point, body and head rough.	W.I.	Length	Diameter. Length. Thread length. Mfrs. stock sizes.	44639 44392	$\frac{3}{8}$" x 8" Lag Sc.
Mach. B. Machine bolt with one hexagon nut.	Square head, rough; body rough and slightly tapered up to head; U.S. Standard threads; Standard hexagon nut.	W.I.	Length	Diameter. Length. Thread length. Mfrs. stock sizes.	44639 44397	$\frac{5}{8}$" x $4\frac{1}{2}$" Mach. B.
M. B. Mach. B. Milled body machine bolt with one hexagon nut.	Square head, rough; body and under head finished; U.S. Standard threads, standard hexagon nut.	W.I.	Length	Diameter. Length. Thread length.	44639 44398	$\frac{7}{8}$" x 9" M. B. Mach. B.

Aug. 8, 01
H. Hollong

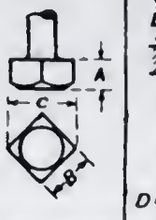
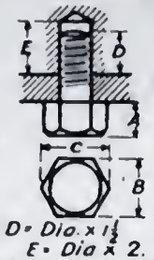
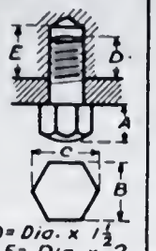
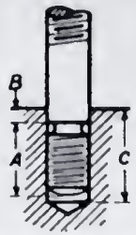
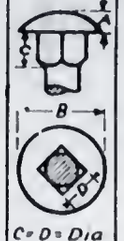
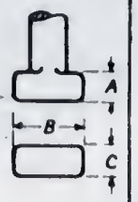
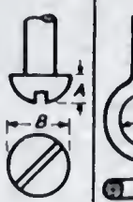
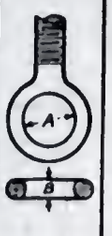
1 2

S. 42585

Fig. 5.

BOLT HEADS, ETC.

Standard Dimensions B-3

	Set Sc.	Lag Sc. Mach. B. M.B. Mach B.			Tap Bolt. M. B. Tap B.			Cap Screw.			Stud.			Btn. Head Bolt.		T. Head Bolt.			Flat Hd. Stove B.		Round Hd Stove B.		Eye B.	
	 A=B=Dia.				 D=Dia.x 1½ E=Dia x 2.			 D=Dia. x 1½ E=Dia. x 2.						 C=D=Dia										
DIA.	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	A	B	C	A	B	A	B	A	B
1/4	23/64	3/16	3/8	17/32	3/16	3/8	7/16	1/4	7/16	1/2	3/8	1/8	5/8	1/8	5/8	3/16	1/2	1/4	9/64	15/32	5/32	7/16		
5/16	7/16	15/64	15/32	21/32	15/64	15/32	35/64	5/16	1/2	37/64	1/2	1/8	3/4	7/32	13/16	1/4	5/8	5/16						
3/8	17/32	9/32	9/16	51/64	9/32	9/16	21/32	3/8	9/16	21/32	9/16	1/8	7/8	3/16	15/16	5/16	3/4	3/8	1/4	3/4	1/4	5/8	1/4	3/8
1/2	45/64	3/8	3/4	1 1/16	3/8	3/4	27/32	1/2	3/4	27/32	3/4	1/8	1	1/4	1 1/8	7/16	1	1/2					1/2	7/16
5/8	7/8	15/32	15/16	1 21/64	15/32	15/16	1 5/64	5/8	7/8	1 1/64	15/16	3/16	1 1/4	3/8	1 3/8	17/32	1 1/4	5/8					3/4	9/16
3/4	1 1/16	9/16	1 1/8	1 13/32	9/16	1 1/8	1 19/64	3/4	1	1 5/32	1 1/8	3/16	1 1/2	1/2	1 5/8	5/8	1 1/2	3/4					1 7/8	11/16
7/8	1 13/64	21/32	1 5/16	1 55/64	21/32	1 5/16	1 1/2	7/8	1 1/8	1 19/64	1 5/16	1/4	1 3/4	5/8	1 7/8	3/4	1 3/4	7/8					2	3/4
1	1 13/32	3/4	1 1/2	2 1/8	3/4	1 1/2	1 47/64	1	1 1/4	1 7/16	1 1/2	1/4	2	3/4	2 1/8	7/8	2	1					2 1/8	7/8
1/4	1 49/64	15/16	1 7/8	2 21/32	15/16	1 7/8	2 5/32	1 1/4	1 1/2	1 47/64	1 7/8	5/16	2 1/2										2 3/8	1 1/8
1/2	2 1/8	1 1/8	2 1/4	3 5/16	1 1/8	2 1/4	2 19/32				2 1/4	3/8	3										2 5/8	1 5/16
3/4	2 19/32	1 5/16	2 5/8	3 21/32	1 5/16	2 5/8	3 1/32				2 5/8	7/16	3 1/2										3 1/8	1 7/16
2	2 53/64	1 1/2	3	4 1/4	1 1/2	3	3 15/32				3	1/2	4										3 1/8	1 9/16
1/4	3 3/16	1 3/4	3 1/2	4 13/16	1 3/4	3 1/2	4 3/64				3 3/8	9/16	4 1/2											
1/2	3 17/32	1 15/16	3 7/8	5 51/64	1 15/16	3 7/8	4 5/32				3 3/4	5/8	5										4 1/2	2
3/4	3 51/64	2 1/8	4 1/4	6	2 1/8	4 1/4	4 29/32				4 1/8	11/16	5 1/2											
3	4 1/4	2 5/16	4 5/8	6 35/64	2 5/16	4 5/8	5 11/32				4 1/2	3/4	6											
1/4	4 19/32	2 1/2	5	7 1/16	2 1/2	5	5 49/64				4 7/8	13/16	6 1/2											
1/2	4 13/16	2 11/16	5 3/8	7 23/32	2 11/16	5 3/8	6 3/64				5 1/4	7/8	7											
3/4	5 5/16	2 7/8	5 3/4	8 1/8	2 7/8	5 3/4	6 41/64				5 5/8	15/16	7 1/2											
4	5 21/32	3 1/16	6 1/8	8 21/32	3 1/16	6 1/8	7 5/64				6	1	8											

Aug 8 01. [illegible]

WESTINGHOUSE ELECTRIC & MFG. CO., PITTSBURG, PA. S44639

Fig. 6.

STRENGTH OF SPUR GEAR TEETH

B 40.

VALUES OF P for 15° involute teeth of 1" face, which produce fibre stress of 1000 lbs. per □"

NUMBER of TEETH in GEAR	CIRCULAR PITCH																	Multiplier for	
	3.146	2.52	2.1	1.8	1.57	1.4	1.25	1.14	1.05	0.98	0.89	0.84	0.79	0.7	0.63	0.57	0.52	20° involute	Radial Flank
	DIAMETRAL PITCH																		
	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4½	5	5½	6		
12	210	168	140	120	105	93	84	76	70	65	60	56	52	47	42	38	35	1.16	.775
13	220	176	147	126	110	98	88	80	73	68	63	59	55	49	44	40	37	1.18	.756
14	226	180	151	129	113	100	90	82	75	69	65	60	56	50	45	41	38	1.22	.750
15	236	189	157	135	118	105	94	86	79	73	67	63	59	52	47	43	39	1.22	.734
16	242	194	161	138	121	107	97	88	81	74	69	64	60	54	48	44	40	1.22	.728
17	251	200	167	143	125	112	100	91	84	77	72	67	63	56	50	46	42	1.20	.712
18	261	208	174	149	130	116	104	95	87	80	75	70	65	58	52	47	43	1.18	.700
19	273	218	182	156	136	121	109	100	91	84	78	73	68	61	54	50	45	1.15	.678
20	283	227	189	162	142	126	113	103	94	87	81	75	71	63	57	51	47	1.14	.667
21	289	232	193	165	144	128	116	105	96	89	83	77	72	64	58	52	48	1.13	.663
23	295	236	197	169	147	131	118	107	98	91	84	79	74	65	59	53	49	1.12	.659
25	305	245	203	174	152	136	122	111	102	94	87	81	76	68	61	55	51	1.11	.649
27	314	250	210	180	157	140	126	114	104	97	90	84	78	70	63	57	52	1.11	.640
30	320	256	213	183	160	142	128	116	106	99	91	85	80	71	64	58	53	1.12	.637
34	327	262	218	188	164	146	131	119	109	101	94	88	82	73	66	59	54	1.14	.634
38	336	269	224	192	168	149	134	122	112	103	96	90	84	75	67	61	56	1.14	.626
43	346	277	230	198	173	154	138	126	115	106	99	92	86	77	69	63	57	1.15	.619
50	352	282	235	200	176	156	140	128	117	108	100	94	88	78	70	64	58	1.16	.615
60	358	286	238	204	179	159	143	130	119	110	102	95	89	80	71	65	59	1.18	.613
75	364	292	243	208	182	162	146	132	121	112	104	97	91	81	73	66	61	1.19	.612
100	371	297	247	212	185	164	148	135	124	114	106	99	93	82	74	67	62	1.20	.610
150	377	302	251	215	188	167	151	137	126	116	108	100	94	84	75	68	63	1.22	.608
300	380	308	256	219	192	171	154	140	128	118	110	102	96	85	77	70	64	1.23	.607
Rack	390	312	260	223	195	173	156	142	130	120	112	104	97	87	78	71	65	1.24	.605

FIBRE STRESSES

MATERIAL	AVERAGE of TESTS Made by W.E. & Mfg. Co.		※ SAFE Fibre Stress lbs. per □"
	Ultimate	Elastic Limit.	
Cast Iron	22000	——	8000
Cast Steel	60000	28000	20000
Forged Steel	65000	31000	25000

※ The safe fibre stresses given here are for static loads acting at point of one tooth.
For consideration of other conditions and methods of figuring applied to motor gears see special sheet.

METHOD OF FIGURING



P = total load in pounds acting on one tooth.
T = tooth thickness at line of weakness.
L = moment arm, normal to P.

Bending moment $M = PL$

Fibre stress $S = \frac{My}{I} = \frac{Ply}{I}$ in which

y = inches from neutral axis to outside fibre $= \frac{T}{2}$

I = moment of inertia at line of weakness $= \frac{ft^3}{12}$ in which

f = face of gear in inches.

From $S = \frac{Ply}{I}$, $p = \frac{ST}{Ly} = \frac{S\left(\frac{ft^3}{12}\right)}{L\,\frac{T}{2}} = \frac{Sft^2}{6L}$

The values of "L" and "T" used in compiling accompanying table were obtained by measurement from a series of tooth layouts.

EXAMPLE: Given a cast iron spur gear of 60 teeth, 3 diametral pitch, 4" face, running at pitch line speed of 700 ft. per min.

(1) What is safe working load P?

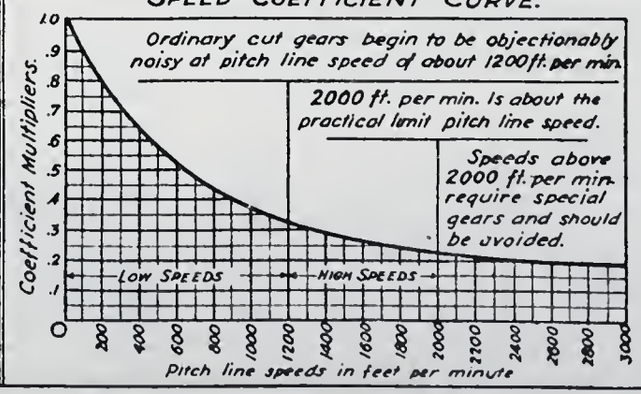
(2) What horsepower will gear transmit?

SOLUTION: From table of values of P, under 3 diametral pitch for 60 teeth, read 119. From speed coefficient curve for 700 ft. per min. read .47. From fibre stress table for cast iron read 8000.

Then (1) $P = 119 \times 4" \times .47 \times 8 = 1790$ lbs.

(2) Horsepower $= \frac{1790 \times 700}{33000} = 38$ H.P.

SPEED COEFFICIENT CURVE.



July 15, '02. A. Y.B.

WESTINGHOUSE ELECTRIC & MFG. Co., PITTSBURG, PA.

S 72313

Fig. 7.

ence. The chart reproduced in Fig. 4 is for the Direct Current Engine Type generator. With this in his possession the draftsman at once knows the official name of every element and part of the machine; he knows what pieces should be detailed separately; the halftone of the complete machine tells its own story and so does the sectional assembly drawing beside it. In talking or writing about or designing any one of these elements that go to make up the machine there is no room for misunderstanding as to the meaning of a term. For instance, the Element "Frame" in this machine includes: frame castings, poles (punchings, side plates, ing, stud bolt and nuts, eye bolts and liners; and so with the other elements.

While settling these matters concerning the names of the principal parts of standard-type machines, we took up the naming of small pieces, as screws and other fasteners, and also much-used parts of machines. The result of this was the Illustrated Index, one page of which is reproduced in Fig. 5. Every draftsman has the complete index and has therefore no excuse for any error in designating any piece included in the index. Of course these books and others that are referred to below grew gradually and are still growing, becoming more comprehensive every month.

In the modern drafting room draftsmen have no time to hunt for dimensions of standard parts. As soon as possible then after a piece becomes standard for general use, every draftsman should be put in possession of its dimensions, so that whenever he wishes to use it he can go ahead promptly and draw it to scale without having to hunt up information.

Every draftsman in the Westinghouse drafting room has a set of 51 sheets containing standard dimensions, and these are being added to every week. The page reproduced in Fig. 6 shows the style in which information of this kind is put up.

Another outcome of the Standard Division is the Engineers' Note Book. One page is shown in Fig. 7. If there is to be uniformity in design of any apparatus or piece where strength has to be figured, designers must use the same method of figuring, and this method should be thoroughly investigated before being accepted as standard.

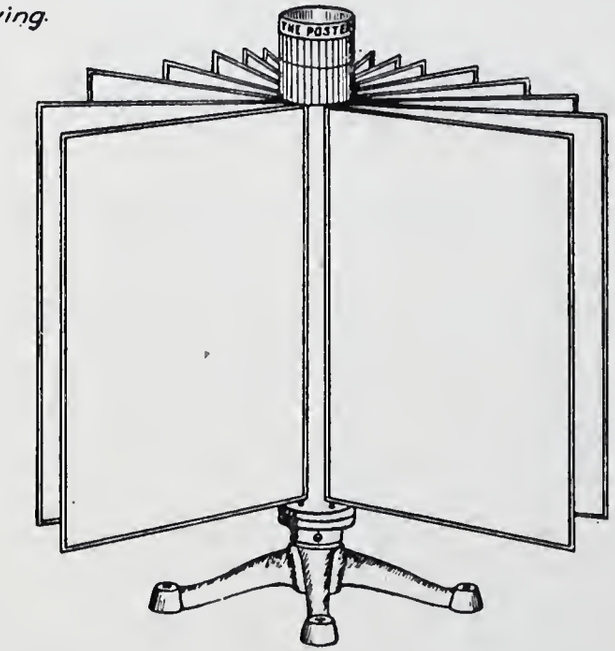
Standard Division Bulletin. 80/3

THE "POSTER" Q-6

The Poster contains up to date information regarding sizes of materials that are kept in stock in the several store rooms of the W.E.& M.Co.; also miscellaneous information that is made sufficiently available to draftsmen by being posted in this way, or that for any reason is not suited to general publication.

At present the stock sizes posted include the following.

All standard bolts, screws and rivets.
Aluminum rod, tube, sheet and bar.
Brass rod, bar, tubing and screen.
Copper rod, blocks, sheet, straps and screen.
German silver strap.
Phosphor bronze and sheet.
Sheet steel, (open hearth, Bessemer, grade B. and galvanized.)
Terne plate, boiler plate, angles and channels.
Cold rolled steel bars, various shapes.
Machinery steel bars, (Bessemer), various shapes.
Galvanized iron screen.



In addition to the above there are four sheets showing the general arrangements of bolts and dowel-bolts for securing machines to bed-plates.

Other data will be added from time to time as information is obtained.

Suggestions regarding stock-size data required by draftsmen should be made to the Standard Division.

The space below is intended for personal notes concerning contents of the poster.

1	June 22,03

WESTINGHOUSE ELECTRIC & MFG. CO., PITTSBURG, PA. S-87112.

Fig. 8.

So far we have dealt only with what may be called internal information. Quite as important to the drafting room and to the concern itself, because of its influence on profit and loss, is information directly connected with the factory; I refer particularly to stock sizes of manufacturing material.

In modern drafting rooms, whether large or small, draftsmen should be kept thoroughly posted as to the sizes of standard parts kept in stock in the shop store rooms. If this is not done, innumerable unnecessary sizes of these parts will gradually creep into use, which means money locked up in unnecessary stock, and just so much more scrap at the end of every year. This posting should cover stock patterns as well as finished parts and raw materials. It is the duty of a modern draftsman to make a choice from stock unless it is absolutely necessary to introduce a new piece. That is where some of the individuality of the draftsman is passing away. The draftsman needs all the ingenuity as designer and schemer that he ever did—he never needed more—but in the modern drafting room his ability should be directed along lines that will result in work of the greatest value to the concern. In the Westinghouse drafting room there is a large swing-leaf poster, see Fig. 8 (japanned sheet metal leaves hinged around a rotating verticle column) upon which stock bulletins are secured by means of clips. This poster stands in a place of easy access and can be referred to by several men at the same time, and fills its purpose admirably, containing up-to-date information regarding sizes of materials that are kept in stock in the several shop store rooms of the company; also miscellaneous information that is made sufficiently available to draftsmen by being posted in this way.

Information regarding existing patterns, dies and tools, etc., is carried for the most part in card indexes.

In every drafting room the Chief Draftsman finds it necessary from time to time to issue instructions; some to the drafting room as a department, others to the divisions of the department. These instructions frequently emanate from the officers of the company, and affect standard practice. Whatever they may be, if they are instructions for permanent following they must be in writing, must be read by all concerned and not forgotten; in

C 14

MACHINE BOLTS.

| DIA. | LENGTHS | | |

other words, these instructions must be carried out at all times.

In the Westinghouse drafting room instructions of this kind are issued as circular letters; the complete book of them at the present time is a volume of about 400 pages of type-written matter, the whole being duplicated six times for reference in different parts of the room.

It is perhaps needless to say that it is practically impossible for any man to remember so many instructions of so varied a character, and quite out of the question for a draftsman to wade through a volume of 400 pages to look up doubtful points of practice. The solution of this has been found in what we call the "Circular Letter Digest." This is a printed book of some 30 pages (and every draftsman has a copy of it), in which the instructions are classified according to the subject they bear upon, and in which the substance of each letter has been "boiled down" or "digested" into the smallest number of words consistent with intelligibility, frequently a single line taking the place of a long letter.

One of the happy results of having information for draftsmen put together in concise and intelligent form is the ease with which it is possible to break in new men.

Reference has been made to the dividing of the drafting room force into designers and draftsmen, tracers, checkers and clerks. In a large concern like the Westinghouse Company, where there is a drafting room force all told of about 350, these divisions are more distinct than in small concerns, but they always exist to some degree and all members of the force must be kept in line. The clerical part of the work must be done on forms prepared for the purpose, so that all records may be quickly made and correspondence with other departments be official in character and uniform in style.

The drafting room (speaking now in general) has been grossly neglected in matters of form and methods of procedure. While the executive end of business has been fully equipped with printed forms for the transacting of every detail of its work, the drafting room has been generally expected to make what it can of blank sheets of paper for drawings and a scratch pad for correspondence. This is not as it should be and in the modern drafting room it is a condition that is rapidly disappearing.

Even the checker, who is generally considered as sufficient unto himself and to have occult powers, should work systematically. The checking of drawings is of vital importance; mistakes are not mistakes until after they have eluded the checker's eye; the drawing like the machine is not ready for delivery until after it has been tested and inspected.

The following are our standard instructions to checkers:

Q-5

CHECKING DRAWINGS.*

The following is intended as a guide when checking drawings. Each numbered feature should be taken up separately for any drawing or set of drawings (generally in the order given), and as each item is taken up it should be done thoroughly and as far as possible completed before passing on to the next. Every dimension, etc., should be ticked off with blue pencil as it is checked, and each feature checked off on Form S-78534 as a record both of what has been done and what remains to be done.

1 – See that the drawing is made in accordance with the Westinghouse standard drawing system, and with the nearest related element chart. This part of the checking should cover the general contents of the drawing information for Specification Department, nomes of pieces and title of drawing.

2 – Check all dimensions by scaling, and, where advisable, by calculation also.

3 – See that each piece is correctly drawn, independent of dimensions; and that all necessary views are shown, but none that are not necessary.

4 – See that dimensions for the shop are given as required by the shop; that is, that the shop is not left to do any adding or subtracting in order to get a needed dimension. Give due attention also to dimensions that are specially for the Specification Dept. or for future reference in the M. E. Dept.

5 – Go over each piece and see that finishes of every kind are properly indicated or specified.

6 – See that every specification of material is correct and that all required specifications are given.

7 – Check the pattern list with the patterns shown on the drawing, and with the pattern book in Standard Division, and also with similar patterns as tabulated in card indexes, etc., to make sure that no new patterns are ordered when old patterns already exist. Check Piece #'s and Die #'s.

8 – Compare with previous drawings of similar apparatus.

9 – Look out for interferences; this means check each detail with the pieces or parts with which it is to be assembled, and see that proper clearances have been allowed.

10 – When checking for clearances in connection with mechanical movements, carefully lay out the movement to scale, figure the principal angles of motion, and see that proper clearances are maintained in all positions.

11 – See that all the small details, as screws, bolts, keys, pins, rivets, wires and cables, insulations, etc., are according to our standard, and that where possible stock sizes are chosen.

12 – In a general way review the drawing in its entirety in connection with any points that have suggested themselves during the above checking; and bear in mind all the information given in the following standard data books: Drawing Dictionary; Standard Dimensions; Stock Sizes; Example Drawings; Name Plates and Name Plate Charts; Element Charts; Finish Charts; Abbreviations; Illustrated Index; Hand Wheels; Flexible and Flange Couplings; Pulleys; Process Book, and all information available in the Standard Division.

13 – Check every feature of the title and record strip.

14 – Attend to all entries and correspondence in any way connected with the drawing.

15 – See that all lines and figures are heavy enough to make good Brownies.

* You must know what is wanted before you go ahead with any checking.

Jan. 5. 1903. WESTINGHOUSE ELECTRIC & MFG. CO., PITTSBURG, PA S 78531

In the Westinghouse drafting room there is a large force of checkers and one inspector. The checkers are expected to follow the above advice. Draftsmen also are provided with the instructions and it is their business to make drawings so that they will check up in accordance.*

Just how these instructions were arrived at may be of interest. One of the most systematic of our checkers was asked to give his ideas on the subject. A copy of his ideas was then handed to every checker in the room, with a request for other ideas; which after being sifted to the bottom resulted in the instructions as above.

The note, "You must know what is wanted before you go ahead with any checking," is an important reminder that speaks for itself. Every drawing after being checked is handed to the inspector, whose special duty it is to catch all deviations from standard in matters relating to the drawing considered as the writing of a language, and under whose advice all records are made (generally on specially-ruled index cards) of such patterns and much used pieces as draftsmen may wish to refer to in connection with future designs.

In general, information to draftsmen belongs to one of two classes: It is either Standard or Special. Under Standard we have in the Westinghouse drafting room the Drawing Dictionary, Element Charts, Illustrated Index, Circular Letter Digest, Example Drawings, and Abbreviations—six books, bound in one cover, with index, and called the Standard Book. Every checker, draftsman and tracer has his standard book, the contents being suited in a general way to the work of the man. Under Special information are included records that have to be kept up to date. In general no attempt is made to post draftsmen individually on information of this kind, it being made as available as possible in other ways, as by card indexes and record books.

In conclusion I would like to point a moral: The mechanical draftsman will be a greater force and will the sooner gain that recognition he so frequently cries out for, when he ceases

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*You must know what is wanted before you go ahead with any checking.

to permit his work to be the mere making of lines, and succeeds in elevating it to a higher plane—the writing of an exceedingly comprehensive and practically universal language. I have heard apparently intelligent men discuss for hours and throw fierce invectives in vain attempts to convince one another that such and such a way of filing drawings is better than any other; that the dull side of tracing cloth is better than the smooth side, or vica versa; that patterns should be numbered in this way and not by any manner of means in that way; that original pencil drawings should always be carefully preserved, or officially destroyed as soon as the tracing is complete; that the bill of material should be in such a place on the drawing, or not on the drawing at all; that there should positively be a margin of one-half of an inch around every drawing; that the size of a drawing should be so much by so much, even according to the law of the Meads and of the Persians; and so on, ad libitum.

Surely all these things have been written about and talked about often enough to prove conclusively that it is waste of time to do either any more. It is as well to remember the old saying, "What is food for one may be poison for another."

Let each drafting room, guided by a little common sense, settle these and similar things for itself, and then go ahead and write the language in such a way as to convey exact information clearly and concisely according to our definition; let the aim of those in charge of draftsmen be to keep them thoroughly and systematically posted; let every draftsman make it one of the essentials of his work to become familiar with shop practice and with everything that the firm he is with has already made or carries in stock or is accustomed to buy, and let his aim be to produce drawings that tell the shop clearly everything that the shop needs to know; let the draftsman do these things and he will get his reward.

Mr. Camp—What have you to say in the discussion of this very admirable paper. It seems to me that the points have all been so well covered that there is not much left to discuss.

(It was suggested that general discussion be deferred until after reading of all the papers.)

MR. CAMP—The second paper of the evening will be one entitled "Drawing Room Practice for Manufacturing Companies," by Mr. J. L. Klindworth, Chief Draughtsman, Jones & Laughlins.

DRAWING ROOM PRACTICE FOR MANUFACTURING COMPANIES

BY J. L. KLINDWORTH.

Some time since, our esteemed ex-president, Mr. Metcalf, spoke of the lowly position the engineering department held in the minds of most manufacturers about 35 to 40 years ago.

Due to the effort of our pioneer engineers and on account of the survival of the fittest, the engineering department has come to be considered of prime importance in a manufacturing concern. A firm which 25 years ago employed one or perhaps two draftsmen, is often found to have a force of from 10 to 20, or even more. The number of drawings turned out in those days being small, there was not much effort made at having a system. Frequently the drawings were not even made of standard sizes, and as for record, it was usually the memory of the draftsman, assisted, perhaps, by a label on the drawer giving the class of work which, however, might still necessitate having to look at most all drawings until the desired drawing was found. The amount of work and number of drawings increasing rapidly, such practice was soon found to be badly wanting. After looking for some avenue of relief from such a state of affairs, a heroic effort was made to systematize the work and record keeping. Those who have gone through such a period know how many points come up for consideration, to make the new system fit the existing circumstances. Of course, any one system will not suit all cases on account of the great variety of engineering work.

The writer is best familiar with rolling mill and steel works practice and the manufacture of rolling mill machinery.

In the following I shall briefly outline the work and system

of an engineering office of a manufacturing concern producing a variety of rolling mill machinery:

The work would involve (1) The making of drawings and prints and keeping record of same; (2) Keeping record of foreign prints; (3) Issuing order; (4) Keeping record of work passing through the office; (5) Miscellaneous, such as indexing catalogues, technical books and correspondence.

It is assumed that the order, together with all necessary information for a certain machine, is received by the engineer or chief draftsman from the estimating or contracting department. The order number being entered, all the time on drawings for same should be charged against it.

Coming now, to the making of drawings, something may be said of size and numbering of drawings, designing, detailing, piece numbers, etc.

SIZE OF DRAWINGS.

Would recommend two sizes. Largest size for general drawing, 21″x30″ on outside, with 3-8″ margin line all around, and regular sheets 15″x21″ for detail or shop drawings. The latter would be numbered consecutively, also the large sheets, but with a letter A preceding the consecutive number. Only a few details should be put on each detail sheet, which is advantageous in a number of ways, quite obvious to those who have had experience in this line. All general arrangements should be made on linen back paper, and preserved after tracings have been made from it.

When taking up the design the draftsman should be furnished with a notebook, wherein to make all calculations pertaining to the design. This book, of course, to remain the property of the company, and which could be referred to in case questions in regard to strength, etc., should come up. The general design being completed, it is usually good policy to let the machine and pattern shop foremen have a good look at it. After that, the details may be drawn out. It is here that great care should be exercised in making such a drawing, which shall show clearly what is wanted.

I might here mention a few points which are frequently overlooked, and which, if done, would help the workmen con-

siderable in understanding the drawing and in erecting a machine. Gears and levers should be shown in connection with their shaft, and always noted from which side the key is to be driven, something, by the way, not one-half of the detailers think of doing.

If the gears cannot be shown on shaft, then it should be indicated where the wheel-seat is, and the mark of the gear given. Another point is concerning diameter of shafts and size of bore for wheel or crank. The shaft should be turned to size, and the wheel bored for whatever kind of fit is desired.

In drilling for bolts, it should be stated what size of holes are wanted, and not as is usually done, drill for $\frac{3}{4}''$ or $1''$ bolts. Where the bolts are not to fit the holes, it is much better to have the holes drilled $\frac{1}{8}''$ larger to allow for errors in spacing. Holes for fitted bolts should be marked, drill and ream. Attention to the above will often save the workman a trip to the foreman and time thereby. In connection with this might be mentioned something about coring holes for foundation bolts, which are invariably made too small. They should be cored at least $\frac{1}{4}''$ larger than bolt diameter for small sizes, and at least $\frac{1}{2}''$ more for larger sizes. A great many additional points might be mentioned, but shall leave that for the discussion.

The tracing I prefer to have made on the dull side of the cloth, because the ink runs easier and any erasures do not injure the surface to the same extent as the glossy side.

The title, firm name, date and number should be in lower right hand corner. Finished surfaces to be indicated by the letter "f," cross-sectioning of all material to be alike; the bill of material is for the purpose of giving what material is wanted.

If the material is changed, as is frequently the case, from cast iron to steel casting, then it need only be changed in one place. The bill of material should also be on the right hand side of the sheet. The bill to have five columns, headed—(1) Piece mark, (2) Number required, (3) Material, (4) Name, (5) Remarks. The lettering should be as plain as possible. All shading and shaded lines should be omitted, for it seldom makes the drawing clearer to the workman, but always takes more time.

Assuming the drawing completed, next in order would be to give the parts a mark of identification. It is here where people differ very much as to which is the best system.

What appears to me the best system for a concern making a variety of machinery is to number the drawings consecutively, filing 50 in a drawer. The pieces to be marked with large letters of the alphabet. A piece A, on drawing 230, would be known as 230-A. This mark should be stamped on pattern, and also be nailed on same with about $\frac{3}{8}''$ metal letters and figures. This mark to appear on castings. Parts on general arrangement should also be marked. If any change is made on a pattern, for instance if used for a different machine, then a new mark should be given, but reference always be made to original pattern mark. Pieces which are what is termed right and left should be marked: 1—Required as shown, A. 1—Opposite hand, B. Some have a system in which a machine is given a number or a letter. This is usually good enough until it is found convenient to use a certain part on two or three different machines, then it proves troublesome. Such a system, furthermore, requires an additional index for machine numbers. The system advocated, however, does not; all that is required is a card index. If one wishes to find the drawing for a certain machine part, he need only take its mark and look up the drawer containing the range of numbers, which includes the drawing number sought. This could be done without having to consult the card index by anyone to whom the system had previously been explained. The drawings, by the way, should be filed in order, the lowest number in bottom of drawer.

So many systems depend for their effective working upon the memory of those in charge. This is altogether wrong, for what guarantee has a firm that their employes will stay with them or not die? If either of these things happens, then there is usually confusion for some time to come.

The giving out of drawing numbers, filing and indexing, should be the duty of a particular person. No draftsman should be allowed to file a drawing. The marking of pieces as mentioned before, adapts itself very well for keeping track of pat-

terns. This can be done by means of the card index, which is kept by the pattern shop foreman or his clerk. The index giving the shelf or bin where pattern is located. All heavy patterns can be kept on the ground floor of the pattern storage building, and all smaller ones on upper floors, in preference to keeping all patterns for one machine together. Patterns of a similar nature can be kept together if so desired. By means of the index and additional slips the whereabouts of the patterns may easily be determined.

KEEPING RECORD OF PRINTS.

This is quite a necessity of any office. It frequently happens that a change is made on a drawing, and prints have to be substituted. If a record is kept of prints, it is quite an easy matter, but not so if one has to depend upon memory. If a print is issued to any department or person, it should be given a consecutive print number, which is easily stamped on. A card with the person's name, print number, drawing number and date is filled out by the blue-print boy, attached to the print, and signed by the recipient and returned to the drawing-room and filed in a case according to drawing number. It might also be desirable to keep an index of name of persons who have received prints, for the purpose of reducing the number of acquisitions of prints by the unscrupulous. If a revision is made on a drawing, it is only necessary to consult the index, reissue prints, at the same time recalling those which are out.

KEEPING RECORD OF FOREIGN PRINTS.

When such prints are received they should be entered in separate index from office prints, always marked date received and a special number given. If they are for a contract, then I should have enough sets furnished, so that the different departments could be supplied and keep one set in the office for record. If of larger size than standard, they could easily be cut or divided and pasted on heavy paper, the pieces marked, and then given a regular consecutive number. The prints should be traced and the tracing filed with the regular drawings.

ORDERING.

All ordering of new and repair work should be done by the engineering department to avoid mistakes. The order sheets of say 10″x13″ to be fashioned after the bill of material on drawing, with columns added for weight, foundry, pattern, and machine work. Enough copies to be made for all departments; one copy, of course, to remain in the office for filing. All order sheets should be sent to the superintendent, from whom they are distributed to the different departments.

A record should, of course, be kept for ready reference, if it should be desired to know what was furnished for a certain order.

KEEPING RECORD OF WORK PASSING THROUGH OFFICE.

The following method is easily kept up and has proven itself quite satisfactory:

To begin with, I keep a small pocket notebook wherein all sorts of notes are entered promiscuously. The notes are afterwards entered in a larger book about 8″x10″, classified as to departments, which, however, could be applied to order numbers as well.

From these notes a daily program is made up. When work is commenced pertaining to a certain item, I mark it with a cross, and when ready to trace with another mark. When completed and checked, the line is crossed out entirely, and when all work noted on a page has been attended to, the leaf is taken out. By doing this, one has only a few pages to watch and leaf through. The notes are written on one side of the leaf only. For unchecked drawings a separate list is kept by the clerk. The entries are made whenever a new drawing number is given out. Opposite the number is given the order number. This record might be kept by card index, but I find the above more convenient and quicker.

MISCELLANEOUS—STANDARDS, ETC.

What are known as standards should be gotten out in book form and given to the men to insure uniformity of details. Record books of pulleys, sheave and gear wheel patterns should also be kept for reference. For gear wheels, a book say 10″x12″

will do. The columns reading from left to right to be marked: Pitch, Pitch Diameter, a wide column for teeth particulars, as (number, form, cast or cut and height above pitch line) face, arms, pattern made for cast iron or steel casting, drawing, mark, date and remarks.

REFERENCE DRAWINGS.

The usual practice is to get the tracings out for reference, which is a good way to wear them out. A much better plan is to have instead sets of prints containing all drawings for a machine. This saves the tracing, and has the further advantage that one has all the information at once. The contents of the set are marked on the binder. For convenience, the sets may be hung on racks easy of access. It is hardly necessary to say that all tracings should be kept in a fire-proof vault.

APPARATUS.

Tables or drawing boards have been devised by the hundreds. Vertical, all sorts of universal, etc., which are good enough for special purposes; but for all-around work a flat table about 3′x7′-6″ with a hinged adjustable drawing board at one end, gives perhaps better satisfaction than the above mentioned.

BLUEPRINTING.

For this, of course, no one would care to be without the cylindrical arc light printing machine. It seems to me that the horizontal style has some advantages over the vertical, on account of the greater ease with which the drawing and paper may be put in. Devices for keeping and cutting the paper and for washing and drying the prints, I shall not dwell upon, as the time and space forbid same.

INDEXING, CATALOGUES, BOOKS, ETC.

Quite a good bit of valuable information is distributed by way of catalogues, and it is well worth the time and expense to file such in a case, easily accessible to the draftsmen. By consulting these catalogues one gets to know fairly well what is going on. Of course, occasionally, a weeding out process has to be instituted, but that is easily done.

In a well-established drawing office should also be found a

library of technical books for reference. The draughtsman should be allowed to take the books home for study and reference, say for a week. A number of technical papers should be kept for the men, after being read, to be bound and kept for reference. By these means the library would grow very quickly and be a good investment indeed.

Lastly, the correspondence between the different departments and outside parties should be well taken care of, to relieve one's memory, and to be able at any time to prove all transactions.

MR. CAMP—We have still another paper by Mr. W. E. Fohl, Chief Assistant to Mr. S. M. Taylor, on "System in an Engineering Office."

SYSTEM IN AN ENGINEERING OFFICE.

BY W. E. FOHL.

This paper will attempt a brief description of an effort, in an engineering business, to have a place for everything, everything in its place, and, what is more important, a method of finding that place. The business in question, that of Mr. Selwyn M. Taylor, was originally occupied with general survey work. At that time the work of the engineer, in connection with coal mines, consisted principally of surveys of mine workings, and the plotting of the same on maps; the engineer following with his survey the trail of workings which had been driven in accordance with the ideas of the owner or the mine foreman. The engineer played an equally obscure part in the important matters of the determination of points for openings, the general layout of the plant, and the character and style of the various structures.

Since that time a rapid evolution has taken place. The engineer is now called upon to determine and report upon the physical characteristics of the tract before purchase, its strategical position with reference to markets and existing railroads; and, in conjunction with the chemist, to report on the quality of the coal. The development of the coal property now demands from the engineer, direction along so many different lines, that he must either combine himself the qualifications of the surveyor, the structural

engineer, the mechanical engineer, and the electrical engineer, or employ and be responsible for others in these capacities. In line with the evolution mentioned, the business being described has been gradually modified until it now concerns itself exclusively with coal mining. This modification has greatly multiplied the number and variety of records; and the care of these demands energetic attention, because in these latter swiftly moving days an engineer cannot afford to wait while his entire office force lays aside its work and assists in a hunt for some particular drawing or document. Aside from this question of economy of time and energy, he is custodian of many valuable records. These he must be able to produce on demand; and if, as frequently happens, they are demanded after having gone out of his custody, he must be able to announce with conviction that they are not lying in some obscure corner of his office, and be able to show by his correspondence who is responsible for their keeping.

It goes without saying that all business is undertaken for profit. Every business, however, has some undertakings that are more profitable than others. In order to show the relative profits of the undertakings of this business the services rendered each client are taken account of separately. The bills rendered to a client, however, must in the ledger be debited to the client under his own name, and the payment of the bills must be credited to him in the same place. To arrive at the profits yielded by the client, his business requires a separate account in which the bills rendered him appear in the credit column. The debit column of this account shows what labor and monies have been expended in the interest of the client; and the difference between the two shows the profit. To avoid the use of two ledgers, or confusion in one ledger, this last named account must be separately designated, which has been done by calling it a "Proposition," and giving it a number. This designation by propositions separates the constituent parts of the business so naturally and conveniently that it has been carried throughout the entire records of the business. Of course, some records have a general value, as well as a proposition value, and some have a general value with no reference to a particular proposition. Such are classified under the head of "Office."

The bookkeeping used is the voucher system slightly modified to suit this particular business and supplemented by the time sheet and the day book. The time sheet is made out weekly by each employe, and gives a detailed account of the work he has done, for whom it was done, and includes a statement of the expenses incidental to the work of the week. The day book has been especially designed to suit the requirements of this business, and in it the distribution of the time and expenses is made to the various propositions. The ruling of this book is too complicated to permit of verbal description, but is so arranged that the bills to clients may be made up direct from it, excepting such items as are paid for them by voucher. From it also the salary and expense charges are collected, passed through the voucher book, and from there debited to the propositions in the ledger. With the use of a comptometer all figures are easily added, both vertically and horizontally; checking their accuracy, and showing at the same time what profit each employe's work yields. A monthly statement of net profits is taken from the books with ease and rapidity. This statement is a synopsis of the bookkeeping, but, like the day book, is difficult of description.

The majority of recent systems for filing correspondence are based on some system of grouping according to subject matter. Reference to a letter is, of course necessary, on account of this subject matter, and this would seem to be the natural way to file it. In practice, however, this introduces complications. To index readily by subjects, each letter should contain but one subject. Many subjects are too closely related to allow of a separation of this sort, and, even when they do submit to separation, the effect is to fill the filing cases with a multitude of short letters. This is not the only difficulty. If a half dozen different people were to assign a subject to a given letter, each one would give it a different subject. Or, if one person is given a letter to-day to subject, and to-morrow is asked to subject a similar one, the resulting subjects will likely show a radical difference.

Three typical requests will show how this problem has been attacked:

REQUEST NO. 1.—A letter is wanted from Smith & Co. regarding boilers for the A. B. C. Coal Co. An examination of the

card index drawers will show a group of cards under the proposition number of the aforesaid coal company. This group will be found divided under the headings, "Names" and "Subjects." Under the heading, "Names," Smith & Company's card will show an odd number for carbon copies of letters sent them and the next even number showing letters received from them. These numbers will indicate were in the unit cases all letters of Smith & Co., referring to this proposition, will be found, arranged according to date. Before being placed here all their subjects have been written on their face. The incoming letters are held together with one rubber band and the outgoing letters by another, so that the one referring to boilers can be procured with little search. It would be difficult to determine a percentage; but a request similar to this undoubtedly covers a large majority of the calls made on the filing system.

REQUEST NO. 2.—All the letters referring to boilers of the A. B. C. Co. are wanted. Under the heading, "Subjects," in the same group of cards will be found a card for boilers, on which is a complete list of correspondents with their numbers locating each one's group of letters. This request is infrequent in comparison with request No. 1.

REQUEST NO. 3.—A letter is wanted from some particular firm or individual, (name either forgotten or the wrong one given). A reading of the subject card may recall the name. If not, all the letters of all the people listed there must be examined. This sounds like trouble, but in actual practice it is found that even this can be done more quickly than a letter can be found in the ordinary system in response to the easiest request, namely, Request No. 1.

The key, then, to the letter filing is, in the case of outgoing letters the name of the addressee. In the case of incoming letters, it is the writer, leaving the subject part of the index in reserve for the rare occasions when the name of the writer or addressee is in doubt, and for the comparatively few times that it is necessary to collect all the letters of a subject.

The drawings, like the correspondence, lend themselves readily to a classification according to propositions in the card index. The question of space, however, does not allow this classi-

fication to be carried entirely through the drawing cases. Here the grouping of the majority of drawings is according to size. These drawings are contained in unit cases of pigeon-holes opening on one side and one end. The inside dimensions of these units are, length, sixty-one inches; width, twenty-four inches; height, twenty inches. These dimensions permit of an arrangement of pigeon-holes that will accommodate rolled drawings, 24, 30, 36, 42 and 61 inches in length. These pigeon-holes are numbered by thousands; for example, all pigeon-holes twenty-four inches in depth are numbered "3000", the first of these pigeon-holes containing drawings numbered from 3000 to 3010. In addition to this numbering, all of these drawings pertaining to propositions are given their numbers in this manner: P. 10-3005. Those not pertaining to propositions are designated as "Office" drawings and marked thus: O. 3006.

Smaller drawings than those mentioned are accommodated in unit cases containing two large drawers each, which will hold sheets of legal cap size placed on edge. In addition to the small drawings, these cases take care of property calculations, which are made on special blank forms; property records, which consist of a typewritten copy of the orginal deed; a plan of the survey; a typewritten copy of the deed description used in making the survey; and a printed form, which when filled in, gives a brief but comprehensive history of the tract, reciting the facts that should be known before entering the tract to remove the coal. Bills of material and specifications are also filed in the same case. They are also used to render available scientific periodicals. These periodicals contain much valuable data that is worthy of preservation. All of them vary in size and all of them contain much matter that is not of value to any one office. In order to get at what is valuable and eliminate the advertisements and other extraneous matter, these are unbound and a very small portion goes into large envelopes into the unit cases. The remainder disappears via the waste-basket.

Recently provisions have been made for the care of two thousand topographical sheets and geologic folios of the U. S. Geological Survey, by the addition of one unit case of flat drawers. The matter contained in these is so easily arrived at

by geographical location that it has been considered not advisable to card index it. Instead the sheets have been numbered and corresponding numbers have been placed on the quadrangles as shown on the key maps furnished by the survey.

Survey notes are taken in duplicating books. The pages of these are so perforated that the original notes can be sent to the office, leaving the carbon copy for the use of the man in the field. Both the original and the duplicates are finally filed in the office in unite cases of the ordinary library size, fitted up with pasteboard compartments holding ten books each.

One card index is devoted to correspondence exclusively. This has already been described. Another is made to take care of all other records, except book keeping. Each of the indexes has two general divisions, one of which is a guide to records pertaining to propositions, while the other, designated "Office", gives reference to all other records, and, at the same time, selects from the proposition records, such as may be of value in connection with future work. As an illustration of this: a drawing of a farm belonging to Proposition No. 5, would be noted in the index under "P. 5", but in no other place. A drawing of a tipple for Proposition No. 5 would be considered as having a value for future reference, and, in addition to being noted in the index under "P. 5", its number would be found in the "Office" division of the index under the subject, "Tipple." The cards for the index devoted to correspondence require no special preparation, but those used for the other index must take care of such a variety of subjects that it has been found advisable to have nine of the more frequently recurring ones printed on each card with a rubber stamp. Economy of space in the drawing cases demands that nothing but tracings shall be filed. This demand must, of necessity, frequently be modified; so that there may be in the drawing cases at one time, a linen backed drawing, a tracing, a blue print and a white print, all of the same thing. One of these drawings may contain information not found on any of the others. These drawings may have different numbers, which fact must be shown on the cards. This is taken care of by stamping on the card a list of the various styles of drawings. This stamping on the

card, the list of the subjects and the list of the styles of drawings, multiplies the usefulness of a single card many fold.

Again, using the tipple belonging to Proposition No. 5 as an example; this may have required a survey consisting of transit running, levels and topography. These survey notes might be in different books, or on different pages of the same book. The card, to start with, has marked on the upper right hand corner, "P. 5", and in the body of the card, "Tipple." Under the printed heads, "running", "levels", "topography", are then marked the figures, showing in which note books and on what pages these notes will be found. Under the heading, "Calculations", figures show the location of the calculation sheets in the unit case; and under the heading, "Estimates", are figures showing the location of the estimate sheet in the same case. The number and style of drawings made of the tipple are similarly shown on the same card by means of the printed list referring to drawings.

The whole system is an attempt to provide a flexible and reliable index by the use of cards, and to provide receptacles to which others can be added without monopolizing office space. This has been accomplished by the use of unit cases of four different styles, one of these styles having two different sizes.

This paper has concerned itself chiefly with the mechanical part of the system under consideration. Care has been taken, however, in the conduct of the business not to give this mechanical end undue prominence at the expense of the personal organization, whose duties are also carefully classified. The principal members of this organization are an engineer, who is responsible for the disposition of the forces in the field and the superintendence of their work; a chief draftsman, who is responsible for the work of the drafting and the care of all records other than correspondence; a stenographer, who takes dictation from the head of the business, and has in charge the filing of correspondence; another stenographer, who takes care of the general stenographic work of the office, in addition to taking full charge of the book keeping; and a chief assistant, who has general supervisory duties, and the sometimes difficult duty of answering the questions propounded by the head of the business in the event of any "knock" in the machinery.

Almost every member of the organization, from the head of the business to the office boy, has spent some thought or labor on this work during the past two years, and on the book keeping outside assistance was secured. No one is prepared to say that the system is the best that can be evolved, but everyone is convinced that it is of value to the business, and that the taking part in work of this sort has great personal value.

DISCUSSION.

MR. CAMP—We will now take up the discussion of the very comprehensive and intelligently-prepared papers which we have had the pleasure of hearing this evening.

MR. BADEAU—There was one point brought out this evening that I would like to emphasize a little further; and that is the statement in the first paper that a mechanical drawing is a book. Now a mechanical drawing is not only a book, but is a particular kind of book, a reference book, and one of the most important parts of a reference book, as of any book, is the index. If we have a good index to a reference book we don't care very much about the other particulars, such as the numbering of pages, size of sheets, etc. There are two ways of making this index—one by the use of a separate sheet and the other by putting it on the drawing. In a great many large manufacturing establishments both methods are employed, but I think there are a few general rules which should govern when making an index for a mechanical drawing. In the first place, every piece should have a number and the index should show such number, material of which made, and pattern number. The piece number should refer only to that piece and to no other, this arrangement to continue so long as that piece is manufactured. If, however, for any reason, it is ever changed in any particular, the piece number should also be changed. By this method similar parts used in different machines can be called for from the same drawing, and a good deal of drawing be saved. If any detail is changed, the number of the original piece is changed so that all drawings calling for that piece will still designate it by the original piece number and not the changed number.

One other point that I would like to speak of and that is the

matter of tracings. I never saw any use in making tracings right along. In the General Electric Company's drawing rooms they use a great deal of cross section paper. The drawing is first made by the draftsman in the regular way on this paper and inked in—sometimes by a draftsman and sometimes by a tracer. Then it is blue-printed and filed as a regular tracing. We found that on a great deal of apparatus this saves much time because the draftsman can draw a great deal by free hand.

Mr. Flanagan—Book makers always put the page number at the upper corners, right and left on the page, we are told. I wish that statement would hold water and that book makers always did do so. But as a matter of fact, even the makers of machine catalogues do not do it. We have at our place now two or three catalogues that have the page number at the lower corners, and others with this number on the middle of the lower margin. When you open the book, you look for the page number at the usual place and it is not there. In short you must make two or three mechanical movements and several mental efforts before you can get track of the page numbers. In my mind, this kind of a system is equivalent to the elegant method now in vogue of sending out books which are not cut. I saw a reference in a technical journal the other day to a certain catalogue which had been issued and in which special attention was called to the statement that it was of standard size, 6″x9″, being, therefore, readily bound up with other catalogues of similar standard size. The journal remarked that the only trouble was the catalogue was really $6\frac{1}{4}$″x$9\frac{3}{4}$″, and instead of opening at the side it opened at the end.

One of the papers refers to a bill of material and, I believe, designated each detail on the sheet by a letter, calling special attention to the necessity of letting one letter stand for a certain device, also emphasizing the necessity of saying exactly what you mean by right and left, that is, not to say in specifying, one detail required "A" right hand, and one detail required "B" left hand. That possibly goes through the shop all right. But the manufacturer, or other party, orders the part looking from the other side and in consequence is apt to wrongly designate the piece he really wants. I believe in doing as Mr. Klindworth states, viz., indicate

on the drawing "A" as shown, "B" left hand, or something to make a perfectly accurate distinction as to what is meant.

As the speaker who has just sat down has remarked, a letter in combination with a sheet number should represent that one detail and nothing else under the sun, even if made from a pattern previously in existence. For instance, if it is a gear which is in every respect like a gear formerly made but with a different bore in it, it should take a different letter. I had a drawing sent to me not long ago for a pipe system and the draftsman had marked the male flange of a given size "A" and the female "B," and in the bill of material he called for so many flanges "A" and so many flanges "B." Along the line he had several pairs of couplings and he gave the pair the designation "C." The print actually got into the shop that way and we had male flanges that were both "A" and "C," and female flanges both "C" and "B." We could take our choice.

I might say in connection with the first paper in regard to the drawing calling for all the figures the shop requires. A few shops make drawings for the pattern makers, and other drawings for the machinist, and still others for the blacksmith, etc. Some people have found this plan an advantage in their business notwithstanding the expense attending it.

Another point is that in a general manufacturing concern controlling their own designs, the size of the castings should be watched. With a little attention to this matter they can determine whether their design will go into any any flask which they use regularly in the foundry, and frequently by a slight change or modification of the casting it can be made to fit existing flasks. I have seen castings a little too big to go on the boring mill; also pieces constructed which were too big to be shipped. In the latter instance, in the particular case I have in mind, it was fortunately structural material, although everything was riveted together before it was discovered. This only goes to show that it is much better to do a little thinking and watching beforehand and not afterwards. As a matter of fact, the piece I mention was very near the shipping limits, so that with some slight modification it could easily have been made to come within the railroad company's requirements.

As to the matter of arranging the drawings in the office, I do not think anyone can do this for anyone else. Each drawing room must work out their own plan or modify what someone else has done, to suit their own peculiar needs. However, one of the most extravagant ways of keeping drawings is to keep all tracings covering one machine in a single drawer. For convenience of design, it is very nice to have all those showing previous examples of, say, a certain type of shears, at hand for ready reference, but it takes an immense amount of drawing room space to do it. If you can afford to do it, however, it is a very good way. Personally I am rather inclined to Mr. Klindworth's bill of material instead of writing beside the detail what is required. In a good many drawings made on this plan, the draftsman forgets to put down how many parts are required, but when he makes the bill of material he sits down and systematically records what is necessary. In addition to this, there are many things on the drawing which do not need to be detailed, such as nuts, bolts, keys, standard couplings, standard car wheels, standard pulleys, and a large variety of other goods that do not need to be more than mentioned. The number required, of what material made, and a letter and number will identify them.

Referring to the method of keeping the large patterns on the ground floor and smaller ones on the upper floor, one of the papers states that patterns so arranged are easily located. This is beyond doubt the most compact method of storing patterns, but the ease with which they may be found depends largely upon the degree of perfection attained in the record system. Storing and caring for a great variety of patterns, some massive and cumbersome, others mere skeleton framework, can seldom be easily done. Success in this particular generally follows more as the reward of constant effort than as the mere result of system followed.

One thing I like to see on a general drawing, that is, a complete list of detail sheets, so that if anybody in the office wants to get at the drawings he knows where to find them from the sheet showing the general arrangement.

I have had considerable experience with the practice of drawing many details upon the same sheet, and the method has many faults, from the shop standpoint at least. It involves the making

of many large prints, or failing this, we will have some half-dozen men all interested in the one print at the same time. Each man will fold the sheet in the manner most convenient for himself, and it soon becomes creased and dirty and generally unfit for use in a dimly lighted shop. Again, if the drawing is used a second time with perhaps a slight modification of one of the details the sheet is too big a thing to make over, and we endeavor to escape doing so by noting the changes upon the blue prints, and we are not infrequently minus a proper record of work done. A better way is to take a small sheet—I use a standard catalogue size, 6 inches by 9 inches—and make a sketch of the required change, giving the sheet a number as though it was a complete drawing and referring by a note to the detail upon the original drawing which is then only to be used as a supplementary to the small sketch. Blue prints are made from these sketches and the originals are retained in the office, constituting as complete a record of all the work done in the shop as if elaborate drawings had been made. As they are only for temporary use they may often be executed freehand, the number and title written without effort at excellence other than that of legibility. No need of care and painstaking for the sake of appearances merely. For showing changes in the flanges of valves, fittings, etc., in the bore, hub length of gears, pulleys, shears; for complete details of shafts, pins or other machine parts of simple forms, these freehand sketches offer the most readily available means where the only requirement is that of getting the work promptly into the shop, and the keeping of a fairly convenient record of work done in the place where such record ought to be kept, viz., the drawing room.

Mr. Ellis—Mr. Klindworth has mentioned the subject of pattern numbers and as I do not agree with his system, for the reason that you get such a long number, for in many cases a small pattern—for instance, a drawing may lie No. 20000, as noted by Mr. Follows—then your pattern number would be 20000 "A," which involves the use of a good many numbers, and as they must be about $\frac{1}{4}''$ wide they take up considerable room. This one difficulty we found when we took up the question of pattern numbers a few years ago. The way we do this, we manufacture a number of different machines and a number of similar machines.

If it is a new machine we give it a number, say 230. We have only gotten up to about 250 now after a number of years in business, and are at least 50 numbers too far ahead through a former man's carelessness in arrangement. In the case of pillow blocks, fly wheels, gear wheels, and things common to all machines, we give them a special number. For instance, we give gears No. "13," and we have 26 times 26 letters before we run out of designations. When we come to 13Z our next number will be 13AA, 13AB, and so on. The drawing number does not signify very much, because we give the machines we are building a number, and if we have a gear on these it will carry machine No. 13, and it will show on the drawing as No. 13A.

We have, therefore, only three letters there to go on the pattern and we call it 13A on the record card as well. When a change is to be made, if it is very much of a change, we generally make a new tracing and it does not change the pattern number. If it is merely a change in the bore of hub or something of that kind, we then put another view alongside of it and the record will show what No. 13A-1 is. When you make your bill of material you have a small number of figures on it. We have our patterns sub-divided in shelves and these shelves are appropriately numbered. All details in connection with, say, machine No. 230, will be stored in one place. If it is a very large housing pattern, or something of that kind, the patterns are stored on the lower floors and those from the details are sent upstairs. Machine No. 230 will have a division by itself and the patternmaker goes there and finds the pattern he wants. The card system is used for keeping track of the drawings and patterns. Machine No. 230 will have a card given to it and any change that takes place will appear on that card. This card shows the pattern numbers at the top, and any change would be indicated as No. 230A-1, etc. We did make large tracings 35″x25″ outside dimension, but we found the same trouble that Mr. Flanagan describes with his large size sheet. Everybody lost time with the large sheets. So we have gradually cut down our sheets until now we make three different sizes, 35″x25″, 25″x18″ and 18″x12″. We put everything possible on the small sheets—18″x12″ is an advantageous size, that is 17″x11″ inside the marginal line—and one piece on each sheet as nearly as

possible. This arrangement is an advantage in the pattern shop, the machine shop, and office. We can also buy standard cases with standard drawers for this size sheet, very easily. There are many advantages in the use of these small size sheets. There are many other things which occur to me in the line of drawings, but that particular one of pattern numbers is a hobby of mine, and I would raise very strenuous objections to putting the drawing number on pattern.

MR. FLANAGAN—As Mr. Ellis says, we might sometimes run out of letter designations. When we first came upon this difficulty, we used small letters and then double letters. I have one drawing in mind where the numbers ran into AAAA, BBBB, etc. Then this was cut down to A2-A3-A4, etc., which gave unlimited scope without duplicating letters.

MR. KLINDWORTH—While at this pattern business, I should like to tell Mr. Ellis that we used a system similar to his, but have done away with it. He speaks of seven-letter designation on a small pattern. Now a little while ago he said that at one time we changed a pattern 20 times. Then again we will say if there are more than 26 parts to a machine, some of the parts would then have to have two letters to designate the pattern. We would then have No. A-B-20, etc. Then again, while you have accumulated 250 machines in the course of, say, the first five years, in the next five years you may increase this list much more rapidly and readily reach 1,000, or numbers with four figures, if we add a part number A-B-20, we have eight. Now if we put that on a small pattern, it will probably look worse than seven.

MR. ELLIS—We are now up to 250, but when these numbers were begun everything was new and as a matter of fact our plan works out as well with 250 as with 50. Then again our numbers do not double up very rapidly. For instance, all shears of one kind and all shears of the same size carry the same machine number.

MR. CAMP—A motion to adjourn is in order.

Meeting adjourned at 11:10 P. M.

CHARLES W. RIDINGER, *Secretary.*

CHEMICAL SECTION.

The regular monthly meeting of the Chemical Section was held in the society's rooms, June 18th, 1903, the chairman, Mr. Craver, presiding.

Owing to the absence of Dr. Phillips, his historical paper, on "Liebig," was not presented.

Mr. Abraham Gross presented his paper, on "The Purification and Estimation of Iodin," which was applauded and discussed by the members present.

CHAS. H. RICH, *Secy. C. S.*

PURIFICATION AND ESTIMATION OF IODIN.

BY ABRAHAM GROSS.

In view of the importance of iodin in the arts and of the apparent difficulty in obtaining it absolutely pure, a discussion of this subject does not appear untimely and may prove of some value. Very few methods have been published in the direction of iodin purification and but one finds favorable mention.

This is the method used by Stas in his researches on the atomic weight of iodin and consists in dissolving iodin in a solution of potassium iodid precipitating the iodin with water drying over calcium nitrate and subliming the dried mass.

This method is criticised by Lean and Whatmough (J. L. C. S. 1899), who state that pure iodin can be obtained by heating cuprous iodid in dried air at 240° C. when the iodin is liberated.

Other investigations on this subject have been made by C. Meineke (Chem. Zeit. XVI., page 1219) and Z. Musset (Zeit. Fur. Anal. Ch. 1091, page 45).

With a desire to obtain a reliable method for purifying iodin it was considered advisable to test the efficacy of the Stas method and to compare the purity of the iodin thus produced with that obtained by other methods which suggested themselves at the time.

Accordingly the following scheme was planned:

1. The Stas method.

2. Washing iodin with water, drying a portion over sulphuric acid, another portion over calcium nitrate and a third portion over calcium chlorid.

3. Mixing iodin with potassium iodid and drying over sulphuric acid.

Each of the above was then sublimed three times after drying.

The first method was carried out according to the directions of Stas, who states that to dissolve four Kilos of iodin a solution of one Kilo of potassium iodid in one Kilo of water was required.

These proportions were found inadequate, for after standing some time with frequent shaking a considerable portion of the iodin remained undissolved.

Several additions of potassium iodid and water were made until complete solution was effected. This was accomplished when the proportions were four of iodin to two of potassium iodid and two of water.

The solution of iodin was then poured into water and allowed to stand until all of the iodin was precipitated. The supernant fluid was poured off the iodin, washed with water until free from potassium iodid. It was then brought upon a filter with sand as a filtering medium and the water withdrawn by suction. The iodin was then transferred to a shallow dish and dried over calcium nitrate, which was replaced as soon as effected by the moisture. The drying continued twelve days. The dried sample was then sublimed three times by a process which will be described later.

In the next three methods the iodin was washed with water fifteen times, and after as much water as possible withdrawn by suction was divided into three portions and dried as previously mentioned over sulphuric acid, calcium nitrate and calcium chlorid respectively.

In conducting this experiment two other points were in view:

(A.) To determine the best drying agent.

(B.) To ascertain whether any chlorin would be set free and absorbed by the iodin when the sample was dried over calcium chlorid.

It may be mentioned here that the calcium nitrate and sulphuric acid were equally efficient as drying agents, but the in-

convenience of constantly changing the calcium nitrate rendered it less desirable.

Each of these samples was then sublimed three times.

The fifth sample was prepared by mixing iodin with pure potassium iodid drying over sulphuric acid and subliming three times.

The iodin obtained by this method was discarded as a white residue remained after each sublimation.

Apparently the potassium iodid was carried over with the iodin vapor.

PROCESS OF SUBLIMATION.

The iodin prepared by the methods previously described was placed in a piece of combustion tubing slightly inclined and resting on a support. Following the iodin was a plug of ignited asbestos to prevent the heated iodin from running down the tube. The lower end of the tube was connected to two tubes containing phosphoric anhydride and one containing calcium chlorid. In this manner the air drawn through was perfectly dry. The upper end was covered by a bottle fitted to a rubber cork to catch any vapor not previously condensed.

Through the cork passed a glass tube which connected to an empty jar as a precautionary measure and in turn to a cylinder containing water and the suction pump. The suction was regulated by the bubbles produced in the cylinder. To prevent any accident from too sudden heating a piece of iron pipe was placed over that part of the tube containing the asbestos and iodin and extending beyond for about four inches. This was protected from the glass by asbestos.

A gentle heat was used and enough suction applied to condense the vapor sufficiently far enough away from the pipe to prevent any liquefaction of the sublimed crystals.

The succeeding two sublimations were conducted in precisely the same manner.

The following method proved itself highly satisfactory in the determination of the purity of iodin.

About two grams of the iodin were placed in a flask, 40 c. c. of water and about four grams of shot zinc added.

The flask was then shaken and allowed to stand with stopper inserted until the fluid was colorless. When all the iodin was taken up by the zinc the solution was filtered into a half litre flask, the residue and zinc hydrate washed with hot water until free from iodin and the fluid made up to 500 c. c.

Fifty c. c. of the solution was placed in a porcelain dish and titrated with silver nitrate, using potassium chromate as an indicator until the end point, a slight brownish color, was reached.

The following results were obtained:

Stas method:

Mean of five determination gave 100.02%.

Second method:

Mean of five determinations gave 99.65%.

A sample of unpurified iodin gave, by this method, 98.83%.

The iodin dried over the calcium chlorid was tested for chlorin according to Fresenius (Qual. Analysis), but none was found.

For comparison a sample of unpurified iodin was tested by the same method and the presence of the chlorin was indicated.

The following summary may be deduced from the foregoing research:

1. The Stas method gave the purest iodin.
2. Sulphuric acid was the best drying agent.
3. The iodin was not contaminated when dried over calcium chlorid.
4. The iodin, when pure, was satisfactorily determined when converted into zinc iodid and titrated with silver nitrate, with potassium chromate as an indicator.

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DESIGN OF SHEAVES AND DRUMS FOR WIRE ROPE.

BY SAMUEL DIESCHER.

Paper read before the Mechanical Section, June 9, 1903.

In designing sheaves and drums used in connection with wire rope, the requirement of strength in them and the life of the rope employed are to be taken into consideration. Experience has shown that a rope lasts longer if the sheave over which it travels, is of comparatively large diameter, than if otherwise. This relation may be based upon the diameter of the rope itself, as a unit, or may be a ratio among two sheaves. While a rope is being bent, the wires, on the convex side of the rope, are made to stretch, whereas those on the concave, or inner side, are shortened. These changes in the lengths of the wires are produced respectively by straightening and by bending of them. As long as these alterations occur under strains within the limit of elasticity of the wire, so long they will not affect its strength. However, since ropes are composed of strands, and these in turn of wires

which are twisted into strands, and these then made into ropes, the wires appearing on the surface of the rope are not in a condition to move so freely as to accommodate themselves to the requirements of the bend, for they are interlocked among each other to an extent that the length within which a wire may be stretched by straightening, or shortened by bending, or buckling, is very small and for this reason any adjustment necessitated by a bend in the rope, will go beyond the exposed portion of a wire, that is, it will extend underneath, where the strand presses against neighboring strands, and on this account the adjustment of wires must necessarily occur under great resistance.

Experience also demonstrates that a rope suffers less if always bent in the same direction, though straightened after every bend, than if it is bent once or oftener in an opposite direction, though in both cases the number and other particulars of the bends are the same.

If a rope were made of parallel wires, the resistence it offered to bending would be equal to the sum of the resistances of all individual wires, and would be very small compared with the resistance that a twisted rope, made of the same wires, offers to bending; for the transverse strength of the rope grows with the square of its diameter, that is to say, if we have two ropes of different diameters but of the same number of wires laid in same manner, the respective transverse strengths of the two ropes would be as the squares of their diameters. Of course this rule cannot be applied to ropes with relation to single wires, because, in the first place, the rope is not a homogeneous body like the wire, and, furthermore, because the individual wires in a rope accommodate themselves to a certain degree to the tensile and compressive strains in the rope when this is being bent. But, as already stated, this accommodation of the wires is limited by the friction produced by the grip the wires have on each other, owing to being twisted into strands.

The smaller the radius of the arc over which a rope is bent, the greater the deflection from a straight line, the firmer is the grip, and the more difficult the adjustment of the wires to the abnormal condition. There has not been found yet a ratio between diameter of rope and sheave at which the life of a rope would

not be affected by its being bent; for no matter how large a diameter we may select for a sheave, the rope will still suffer more than if it would always remain straight while in tension. For this reason all that can be said in relation to the diameter of a sheave is: Make it as large as the conditions in each case permit. As a guide in the negative direction it may be said that the diameter of the sheave or drum should never be less than forty-eight times that of the rope, that is twelve inch sheave diameter for every quarter-inch of diameter of the rope. This rule was in vogue until about 15 years ago, since when manufacturers recommend larger minimum diameters, but, whether or not this requirement can be satisfied depends in every instance on local conditions.

Concerning the design of the sheave is to be said that if the rope passing over a given sheave remains in the same plane when entering the sheave groove as well as when leaving it, then the groove should be so curved as to fit the rope around two-thirds of the latters circumference. In such case the flanges need be only small because there is no deflecting tendency to cause the rope to jump out of the groove and, therefore, a deep flange is not needed.

In cases where the rope deflects from the direction of the groove, it is usual to make the bottom of the groove according to a larger radius than that of the rope, because there is always torsion at the point where the deflection occurs, as the rope continuously assumes a new direction toward right or left. This deflection necessitates that the inner faces of the groove flanges be so flared that the rope will not come in contact with them before the sheave is worn to the limit of its usefulness.

The exchanging of sheaves in service is a very expensive and awkward job, since they are usually located out of sight, underground, or otherwise difficult to get at. For this reason some years since are so constructed that the rim with groove, which is the only portion subject to wear, is cast separately, so that the main part of the sheave, consisting of hub, arms and solid rim, is cast in one, and the other part containing groove and flanges is another casting; this latter is bored and finished to fit the rim of the main body and is then split into segments, to be bolted together.

If a grooved part of this design is worn out, it can be exchanged without much inconvenience, great expense, or loss of time, by taking one or two segments off at a time, as far as they are not covered by the rope, and new ones put in their places. This can be carried out without removing the rope, by periodically turning the sheave from under the rope sufficiently to make the portion to be worked on free from the rope and thus accessible.

What was said before in relation to the diameters of ropes and sheaves applies also to drums, with this difference, however, that on a drum there is practically no abrasion, since every point of contact between rope and drum surface is touched by the rope only once, then the rope comes to rest there, whereas any point in the groove of a sheave comes so many times in contact with a traveling rope, as the circumference of that sheave is contained in the length of the rope. A further difference in favor of the life of the drum is that the sheave is set in motion by the friction the rope produces in the groove, which owing to the tendency to slip, encreases the wear too, whereas a drum is driven by an engine, or other motor, hence not subject to abrasion by the rope.

Considering the drums as usually employed for hoisting purposes, as, for instance, at inclined planes, mine shafts, etc., their working surface is either of cast iron or of wood. In the latter case the drum consists chiefly of two cast iron spiders, with flanges for the support of wood laggings that are put on like staves to form a barrel, and firmly bolted. The thickness of these staves must be determined in accord with the collapsing pressure exerted by the rope when wound around the drum. This wood covering wears out by mere pressure from the rope, so that it must either be renewed from time to time or protected by a covering of about an inch thickness nailed on top of the staves and easily renewed when worn out, whereby the more expensive lagging is saved entirely from wear.

More recently drums are being constructed entirely of iron; that is either cast in one piece or built up of a number of castings. Drums employed on passenger inclined planes, where also safety ropes are used, must be so designed that their working surface is large enough to accommodate the whole length of the hoisting rope in a single layer, otherwise the use of the safety

rope will lead to complications and trouble. This frequently necessitates very large drums, and if the length of the rope is such that it cannot well be wound upon a drum without doubling or still further multiplying the layers of rope thereon, then it is preferable to adopt friction drums. This latter type of drums is installed in pairs, tandem fashion, as seen on cable railways. Such drums have very narrow faces as they never carry more than six coils of rope wound around both drums simultaneausly, by covering only half circles on each drum. In this case the rope is endless, and not permanently fixed to the drum, but holds to it only by friction produced by a special apparatus that keeps the rope in tension, or by the weight of the cars, as for instance on an inclined plane. These drusm are very much subject to wear because the rope is constantly slipping, which is induced by several causes, namely: by decreased friction between rope and drum surface owing to the necessity of having the rope occasionally oiled, and also in consequence of dampness, both of which causes appear only periodically, as their nature explaines; but there is another cause that is permanent and more serious than the former, namely slipping induced by a difference in diameters of the bottoms of drum grooves.

The rope passing over a pair of tandem set drums, describes a line like the thread of a screw on a cylinder of oval cross section; for, although the grooves on the two drums are mere ring-like depressions, that begin as well as end each in itself, yet by shifting both drums laterally by a space equal one-half that between two adjacent grooves, the rope can be so wound around both drums that when it covers half a circumference on one, it passes to the other drum and covers have a circumference on this, then back again to the first drum, etc., until all the grooves on both drums are occupied, after which the rope passes off in a tangent similar to its entrance of the first groove. Experience has shown that the groove which receives the rope as this latter enters the power house, is most subject to wear. This wear diminishes gradually toward the last groove, the one from which the rope passes out of the power house. Assuming, for illustration, that the drums have each six grooves, and that only one of the drums is driven by the motive power, and that the other drum were a

mere idler, which is in most instances the case, and let us further assume that the last or sixth groove still retains its original diameter, that is, measured from groove bottom to groove bottom through the center of drum shaft, and that each of the other groove diameters is one-sixteenth of an inch smaller than that of the preceding one, then it follows that diameter No. 1 will be five-sixteenths smaller, No. 2 four-sixteenths, No. 3 three-sixteenths, No. 4 two-sixteenths, and No. 5 one-sixteenth than that of No. 6. This means also that the corresponding circumferences are respectively smaller by, approximately, 15-16, 12-16, 9-16, 6-16, and 3-16 than that of groove No. 6. And this further demonstrates that beginning with groove No. 1, and passing to No. 6, with every revolution of the drum each succeeding groove demands three-sixteenths of an inch more rope than the preceding one, thus producing a shortage that grows by three-sixteenths of an inch with every groove from first to last, so that No. 6 wants fifteen-sixteenths, or almost one inch, more rope with every revolution of the drum than the first groove takes on, and as there is no other way to compensate this continuous descrepancy, it is evident that the rope must continuously slip. The unavoidable consequence of this is continuous and accelerated wear of the grooves, and a gradual increase of rope strains to the point of rupture.

Some other consequences are, cutting of the rope through the rim of the drum, but there are also instances of drum shafts breaking; the probability of the latter occurance is easily explained if we consider the force exercised by ten or more steel ropes coiled around the two drums and doing all their combined strength can do to make those two drums come together, working precisely on the same principle as differencial chain blocks.

To meet this exigency, there have been designed and built drums in which the grooves are not cast or sunk into the rim of the drums, but the latter have flat faces, like pulleys, and are provided with wrought iron separate rings, of which each contains one groove, these rings are loosely fitted upon the face of the drum and clamped sidewise. They are held from slipping with the rope, first, by friction caused by the rope as it presses the ring against that drum face, and second, by clamps applied laterally

against the sides of the rings whereby the friction is so controlled that a ring may be allowed to slip whenever the strain in the rope it carries exceeds the resistance produced by that friction, and in this manner the wear is not only very much reduced, but any irregularity in the diameters of the grooved rings is compensated without detriment to either machinery or ropes. This type of drums has been carried out often, and it worked satisfactorily in every instance.

The ordinary hoisting drum with the rope permanently attached, is subject to considerable strain that tends to collapse it. This tendency is not affected by the diameter of the drum, but by the number of coils wound around its face. The total pressure that one winding of rope exerts in the direction from the circumference toward the center of the drum, is the same in a drum of small diameter as in a big one; it is in all cases 2 x 3. 1416 times the tension in the rope. Thus if a drum is built of spiders and staves, and the latter do not fit perfectly against each other, as, for instance, the staves do in a tight barrel, then each of the staves is loaded in the manner of a beam resting on two supports, and must be calculated as such. Supposing we have in consideration a drum the circumference of which is 36 feet; the rope to be 1-$\frac{1}{2}$ inches in diameter, and strain in the rope to be seven tons, and there be 20 coils wound around the drum, and the face of the drum to be made up of 36 staves, each one foot wide, then the transverse load bearing upon every one of the staves will be:

$$\frac{2 \times 3.1416 \times 7 \times 20}{36} = 24.43 \text{ tons.}$$

As it is advantageous to the preservation of the rope that the coils should not touch each other on the drum, since that would cause them to rub against each other, it is good practice to leave a clearance of an eighth of an inch between adjacent coils; thus 20 coils of 1-$\frac{1}{2}$-inch rope would occupy 20 x 1-$\frac{5}{8}$ inches = 33 inches, and this would be the length of the stave as far as it is loaded, and in accord with this, its transverse strength is to be calculated.

Cast iron staves are best made of hollow prismatic shape, as this affords the greatest strength at the least expenditure of material. The working surface to have grooves cast in for the re-

ception of the coils. These grooves should form a thread around the drum, extending from one flange to the other. At both ends of the grooved portion of the staves, blank spaces to be left for fastening of the staves, as well as for the accommodation of one and a half or two dead coils of rope put on merely to produce sufficient friction on the periphery of the drum, so that the rope shall not pull too hard at the point where it passes through a hole in a stave to the shaft, and is wound around the latter and clamped there. Without these dead coils the rope is apt to suffer in the sharp bend at the hole mentioned.

Drums covered with cast iron staves are very expensive, on account of their great weight, and much skilled labor required in bringing the staves to a close contact with each other, and a good fit in general. Therefore, it is commendable to have drums cast in a whole, including the grooved face. With the facilities of modern foundries, there is no limit to casting drums of any diameter and width, as far as their employment is practicable. Drums of large diameters can be moulded within brick walls and without patterns, by means of a revolving templet, as is now frequently done with large cylinders and other circular objects. For convenient transportation such a drum may be split in two or more parts that will come within dimensions that can be shipped by rail. In this case lugs must be cast on for bolting the sections together at erection.

The strains produced by coiling a rope around a drum cast in the whole, do not directly tend to collapse the drum, as if it were formed of separate staves, but in this case the tendency is to crush or buckle the material, which in turn would result in a collapse.

The crushing force produced in the circumference of such a drum is equal the tensile strain in the rope; that is to say, if we wind one coil around the drum, then the crushing force in the metal covered by the rope, is precisely equal to the tension in the rope. And the total crushing strain produced in the circumference of the drum is equal the sum of the strains of the coils wound around the drum. This being known, it is easy to ascertain the thickness of metal necessary to resist crushing.

HIGH GRADE WIRE ROPE.

BY L. C. MOORE.

Paper read before the Mechanical Section, June 9, 1903.

The object of this paper is to consider the properties of standard cast steel, extra strong, and plow steel rope. Also the wires from which these types are made, at the same time confining the line of discussion close, to those made of round wire, laid up into round strands, as it is undoubtedly a fact that fully 95 per cent. of all the wire rope made is constructed in this manner and that other styles have so far, only gained a foothold as "standing rope," otherwise their general adoption would have followed.

It seems to be the case that American manufacturers of steel have, so far, been unable to produce a grade of stock from which wire could be made that would successfully come up to the prescribed and uniform tests required by the most experienced producers of wire rope; and there seems to be no apparent reason for the above conditions, except that mills making this class of stock find it more profitable to run on large orders for general purposes, while the wire rope stock is special.

There is a certain percentage of so-called cast steel rope (and possibly some plow steel rope may be included), made from domestic billets, and with what ultimate success the maker thereof alone knows, as it is not presumed any one in attempting to use this steel, for the purpose of making these grades of rope, would permit the fact to become known, or even expect to receive market prices for his product; and it is well known that the oldest and most reliable manufacturers do not risk any experiments of this nature, or make any high grade rope from any but the best imported steel.

Steel wire rods—acknowledged to be the best for making either of the three grades of rope referred to—are imported principally from England, Scotland, and Germany. A very large proportion of which is made by experienced producers of steel for

this purpose, and in some instances they are large manufactures of wire rope. Thus it will be noted they are undoubtedly versed in our requirements from their practical experience.

Those of the American makers of wire rope, that do not have the necessary facilities for manufacturing wire, import same to some extent, but the facts are, the most experinced producers make their wire from imported rods or billets. Thus they are able, by means of the exertion of care through the various stages of the work, and also by physical tests, to grade the finished product in such a manner that each reel of rope or special order is absolutely uniform, both in tensile strength and ductility.

It is thought unnecessary to consider any of the details of making tempered steel rope wire, other than by a reference to the tempering process as one of the greatest importance; and the careful management does not fail to use extreme caution and to insist on the very best results, not only employing expert labor, but supplying the most accurate means of determining the quality of the finished product, which must not be allowed to vary more than .001" in diameter in any one size for rope wire.

In the physical laboratory records are preserved of all tests made for future reference, and the most popular methods in use for obtaining this necessary data, are considered as follows: The tensile strength test is the same in all instances, if each end of a coil of wire is up to requirements it is so marked.

Practice has not yet fully determined as to the best method of arriving at the comparative ductile qualities of steel rope wire. The old way includes torsion, elongation, and the bend test. It is not necessary to explain the details of the two former, but the latter test is accomplished by clamping one end of the specimen between two jaws, the upper edges or lips being hardened steel and made round, usually to a radii of four times the diameter of the wire in each case, and the arrangement is such that the wire can be flexed through an arc of, say 180°, and if the number of bends before fracture falls below that which is required by a previously prepared table, the coil is rejected, or, if otherwise, it is so marked.

Referring again to the diversity of opinion as to the test of ductility, with the new method, the torsion and elongation tests

are eliminated, owing to one fact, that both are carried at once beyond the yield point, and as a means of determining ductility are not considered reliable; and to another, that wire rope when installed is not subjected to either of these strains, or, if so, the elastic limit has been exceeded and the ropes in question rendered unfit for further use.

Considering the new method of physical research, as before stated—torsion and elongation being abandoned for the reasons given—the principle of applying the test for ductility is in a machine so arranged that the tensile strength of the specimen can first be determined and recorded; and in making the bend test, the operation is such that the load, which the single wire would be subjected to when installed in wire rope, can be applied while flexing the specimen. Thus it will be noted this test of the wire coincides with the conditions of its use in rope.

This machine is also adapted for making physical tests of wire rope and comparing the quality of two or more pieces of rope made in the same or different style from different manufacturers. This investigation requires sample pieces, say 30 inches long, and the method of arriving at and finally determining the emrits of same is accomplished in the following manner:

The wires of the test piece should be unlaid and each numbered consecutively, as tested, from one up. The tests should be for tensile strength, and the bending test; the latter under the individual load that it is proposed to subject the wire to, is installed as ropes, using in every case bending jaws of the same radius for the same diameter of wire.

By keeping a careful record of these tests, as made, and comparing the results, will determine beyond a doubt which piece of rope would show the best results if installed under the same conditions.

All authorities seem to agree "that the most serious wear on wire in rope is due to constant bending over sheave wheels or drums when under stress, and that the deterioration increases proportionately with greater speed or load." Therefore, to make a quality of rope that will handle the greatest possible tonnage, the manufacturer must select wire that will show the highest tensile strength consistent with proportionate ductile qualities.

The question of wire rope machinery requires no consideration, except to say that all details in well regulated manufactories are kept up-to-date.

Regarding various lengths of lay or "Lang's lay" in wire rope, there are some slight differences of opinion; the ideas are usually advanced like those of commonly called patented ropes, with a view of attracting attention. Comparing six strands of seven wires each, with six strands of nineteen wires, each type is adapted for certain conditions.

As to the respective merits of standard cast, extra strong, and plow steel rope, the former is the more popular, owing, perhaps, to the fact that a large proportion of wire rope consumers hesitate to try either of the latter, having in some instances formed the erroneous idea that these styles of rope, being high in tensile strength, do not possess the required toughness or ductility for efficient service.

Experience has demonstrated that wire of the requisite quality for either extra strong or plow steel rope, will not show a reduced number of bends before fracture under the same conditions than will cast steel. Also, wire for these high grade ropes, being harder, resists abrasion longer than the lower tensile strength stock; therefore, this property has a tendency to prolong the life beyond that of cast steel. There is so slight a difference as to flexibility between cast and plow steel that it hardly requires consideration.

If the above arguments as set forth are correct, it would appear that plow steel rope is the best for all purposes, and that extra strong is, we will say, a medium between the former and cast steel.

The style of rope known as eight strands, of nineteen wires each, is made with the object of obtaining greater flexibility. This rope will prove satisfactory if the conditions are favorable; as, for instance, sheaves should be grooved and drum scored exactly to the diameter of the rope, and the latter should not be permitted to ride or overlap on the drum; also to insure a high efficiency, the factor of safety ought to be not less than 7 to 1.

There are also various combinations of different sizes of wire used in making any one diameter of rope other than those hereto-

fore referred to; as, for instance, that known as six strands of sixteen wires each. The object of this style is to combine pliability and larger outside diameter of the exposed wires; as, for instance, one inch diameter rope, 6 x 16, the outside wires of each strand would be .084" and the saem diameter of rope 6 x 19, the outside wires would be .067" diameter.

There is also a popular type of 6 x 19 rope made of three diameters of wire; one size for the core, and the outside wires being alternate diameters, the object of which is to preserve all the pliability of regular 6 x 19, and at the same time one-half of the exposed wires, being much larger in diameter, are presumed to take the most severe wear, thereby protecting the intermediate or smaller wires.

The highest efficiency is denoted with any style of rope, and in all cases where the abrasion of the exposed wires show that they are worn nearly one-half through before fracture takes place. If, on the other hand, the wires break square before abrasion to any extent has taken place, it is evident that something is wrong with the conditions, and if, say, 40% of the exposed in each length of lay are broken, it is time that some move is made towards reconstructiing and improving the plant, if possible, and installing a new rope.

In concluding this subject, a reference to the small lists published by the experienced manufacturers, will demonstrate that they print and distribute gratuitously all the data possible in so short a space, in addition to which at all times they are ready to take up and discuss with their customers any problem that may arise, giving without cost the benefit of in one or two instances more than fifty years of experience.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

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The two hundred and thirty-seventh regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's House, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, Sept. 22, 1903, at 8:15 o'clock, First Vice-President James M. Camp in the chair, and 94 members and visitors present.

The minutes of the previous meeting were read and approved.

The Board of Direction reported that they had passed favorably on the following applications for membership and present same to the Society for action:

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY
JAMES M. BARRETT,	Manager, Liberty Market Co. & Liberty Ice Co. h., 6214 Sellers St., Pittsburg, Pa.	D. Ashworth, V. Beutner, N. C. Wilson,
G. P. BARTHOLOMEW,	Chief Engineer, for The Rochester & Pitts. C. & I. Co. Punxsutawney, Pa.	W. B. Hough, C. W. Ridinger, H. D. Hershey.
WM. W. CONNER,	Salesman with Cahall, Sales Dept. h., 434 Atwood Street, Pittsburg, Pa.	N. C. Wilson, J. Hare, J. W. Landis.
CHAS. F. FRANSON,	Chief Engineer, James Stewart & Co., Westinghouse Bldg., Pittsburg, Pa.	F. Engstrom, P. Brynn, J. H. Tompson.
ERNEST C. HARPER,	Draftsman, with Riter-Conley Mfg. Co., 55 Water St., Pittsburg, Pa.	M. A. Gilbert, F. S. Rice, Z. H. Sikes.
JAMES W. HAYS,	Electrical Engr. & Contractor, Schmidt Bldg., 5th Ave., Pittsburg, Pa.	W. G. Wilkins, J. F. Kuntz, W. M. Judd.
SAMUEL R. JENKINS,	Resident Engineer, on Construction Ambridge Plant, American Bridge Co. h., Economy, Pa.	W. G. Wilkins, J. F. Kuntz, F. G. Ross.

WM. W. KEEFER, - Asst. Gen'l. Supt., - { G.W.Schluederberg, E. J. Taylor, C. W. Ridinger.
Pittsburg Coal Co.,
232 Fifth Ave., Pittsburg, Pa.

RALPH E. MILLER, - Draftsman, - { M. A. Gilbert, F. S. Rice, Z. H. Sikes.
Riter-Conley Mfg. Co.
55 Water St., Pittsburg, Pa.

EDWARD J. MOORE, - Mechanical Engineer, - { J. F. Kuntz, W. M. Judd, L. P. Blum.
with W. W. Lawrence & Co.,
Pittsburg, Pa.

CHAS. L. McKENZIE, - President, - { N. H. Finley, J. W. Walker, H. H. McClintic.
Pittsburg Construction Co.
General Contractors. 207 Bissell Block, Pittsburg, Pa.

WM. PIEZ, - Structural Engineer, - { W. M. Kratzer, A. D. Neeld, F. S. Rice.
G. L. Bollinger Co., Pittsburg, Pa.
h., The Narcissus, Bruston Ave. & Tioga St., Pittsburg, Pa.

ALEX. Z. NEWLIN, - Foreman, - { H. G. Wardale, L. C. Weldin, F. Z. Schellenberg.
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National Tube Co. 1719 Frick Bldg., Pittsburg, Pa.

DAETON PARNELY, - Clerk at Plant Furnace, - { W. E. Prindle, C. H. Rich, A. Curry.
Clairton Steel Co.,
Clairton, Pa.

C. D. SUPPLEE, - Asst. Engineer, - { W. E. Prindle, A. Curry, C. H. Rich.
St. Clair Terminal R. R. Clairton, Pa.
h., Elizabeth, Pa.

ANDREW J. TAYLOR, - Draftsman, - { J. McLean, F. S. Rice, Z. H. Sikes,
Riter-Conley Mfg. Co.
h., 1130 Ross Ave., Wilkinsburg, Pa.

ERNEST P. WHITTEN, Resident Engr. for East { S. A. Taylor, H. W. Gibson, C. W. Ridinger.
Pittsburg Improvement Co.,
Trafford City. h., Stewart Station, Westmoreland Co., Pa.

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JOHN S. PECK, - Electrical Engineer, - { C. F. Scott, S. M. Kintner, R. S. Feicht.
Westinghouse Electric & Mfg. Co.
P. O. Box 911, Pittsburg, Pa.

J. WM. SMYTH, Salesman Insulated Wires for Electrical Purposes for Jno. A. Roeblings Sons Co., 109-111 Wood Street, Pittsburg, Pa. { S. Diescher, A. J. Diescher, L. C. Moore.

R. G. SOMMERFELD, - Manager, - { K. F. Stahl, S. H. Stupakoff, H. W. Bernard.
Sommerfeld Machine & Mfg. Co.,
224 Third Ave., Pittsburg, Pa.

PER LEE ARTHUR YOUNG, Mechanical Engineer, { H. D. Lufkin, W. M. Judd, L. P. Blum.
W. E. & Mfg. Co., E. Pgh., Pa.
h., 724 Whitney Ave., Wilkinsburg, Pa.

It was moved and seconded that the Secretary cast the ballot in favor of admitting these gentlemen to membership.

Secretary read letter from the American Society of Civil Engineers of St. Louis, as follows:

To the Engineers' Society of Western Pennsylvania, Pittsburg, Pa.:

The American Society of Civil Engineers has appointed the above named Committee to represent it at the Universal Exposition, to be held at St. Louis in 1904, to commemorate the Louisiana Purchase.

It is the purpose of the Committee to collect and present an exhibit of plans, photographs, models and descriptions of American engineering works, principally work designed by members of the American Society, which it is believed will be of great interest both to laymen and engineers. It is intended, also, to make the headquarters of the Society, which will be in the Liberal Arts Building, a center of information as to other exhibts in the Exposition, which may be of engineering interest. There will also be a register, which will help one to find and meet his friends, and it is hoped that the headquarters may serve as a rallying point and rendezvous for all visiting engineers.

The members of the Engineers' Society of Western Pennsylvania are cordially invited to avail themselves of the conveniences to be provided by our Society during their visit to St. Louis and the Exposition, and it is hoped that a large proportion of them will be able to do so.

By order of the Committee.

H. J. PFEIFER, *Secretary.*

VICE-PRESIDENT.—This invitation to the Engineers' Society of Western Pennsylvania to make use of their facilities at St. Louis is certainly very courteous, and it has been thought best to read it here and publish it in our regular proceedings.

If there is no further business, we will call on Dr. Lloyd for his paper on "Electrical Measurements as Practiced at the National Bureau of Standard."

ELECTRICAL MEASUREMENTS AT THE NATIONAL BUREAU OF STANDARDS.

BY MORTON GITHENS LLOYD, PH.D.

Next to the scientist, or perhaps equally with him, the engineer and the manufacturer come first in the demand for measurements of precision. It was to satisfy this demand that the National Bureau of Standards was established, and at a previous meeting Dr. Stratton, our Director, has told you of the purposes, the work and the aim of this Bureau, and of the preparations being made for its future usefulness.

It falls to my lot this evening to go more into detail concerning the electrical measurements carried on at the Bureau of Standards. This work is under the direction of the physicist, Dr. E. B. Rosa. The work in absolute measurements is carried on by Dr. K. E. Guthe, while Dr. F. A. Wolff has charge of the precision measurements in resistance and electro-motive force.

In taking up the question of precise measurements, the first thing to be considered is the units employed. Every electrical engineer is familiar with the vicissitudes through which the electrical units have passed, and confusion is easily reached by delving, for example, into the various units of resistance which have held sway in England at different times, such as the B. A. unit, the legal ohm, the true ohm, etc. This multiplicity of units has been occasioned by the attempt to make the practical units agree with the C. G. S. units, and with increasing facilities for precise measurement, there have been many steps in the evolution of the practical representations of the theoretical definitions of the units. The ohm, the ampere and the volt are meant to be respectively 10^9, 1-10 and 10^8 times the C. G. S. unit in the electro-magnetic symtem, and when used without qualifying prefix (such as "legal" or "international") these values are usually understood

The Electrical Congress at Chicago in 1893 adopted practical definitions which corresponded as nearly as was then known to

the above multiples of the C. G. S. units, and these were dubbed the international ohm, international ampere and international volt. By the Act of Congress, approved July 12, 1894, these, and the units of quantity, capacity and inductance derived from them, were made the legal units in the United States. The international ohm is the resistance offered to an unvarying current by a column of mercury at the temperature of melting ice, 106.3 cm. long, of uniform cross-section, and of mass 14.4521 grams. The international ampere is the unvarying current which deposits silver from a silver nitrate solution at the rate of .001118 gram per second. The international volt is 1000/1434 of the E. M. F. of a Clark cell at 15° C.

It was a grave mistake to specify concrete definitions of all three units at the same time that the relation expressed by Ohm's equation is assumed to hold between them. For, with this relation, any one of the units is defined as soon as the other two are defined. At the time the definitions were adopted, the three definitions were supposed to agree, but the absolute determniations, which have since been made at the Physikalisch-Technische Reichsanstalt in Germany, show them to be in disagreement. It was there found that the concrete definitions of the ohm and ampere agree with the theoretical definitions, whereas the concrete definition of the volt does not. The latter has therefore been discarded and the value of the Clark cell at 15° C. is taken to be 1.4328 international volts. In this country the concrete definitions of the ohm and volt have been retained, since they are the ones most generally used in practice. The result is that there is a discrepancy of nearly .1% in the units of measurement of current and voltage in the two countries. It is earnestly to be hoped that the International Electrical Congress, to be held in St. Louis in September, 1904, will take up this question and reach an international agreement which shall bring uniformity of units throughout the world.

RESISTANCE.

The resistance standards at present possessed by the National Bureau of Standards. The Bureau is now preparing to set up mercury standards in accordance with the legal definition of the

ohm. Glass tubes of uniform bore have been obtained and calibrated. The best of these have been picked out and will soon be set up. End pieces, of such shape that the corrections may be calculated, will be used, and they will be provided with potential terminals as well as with current terminals. The mercury is introduced in *vacuo,* in order to avoid bubbles or films of air. * Several varieties of mercury standards will be set up. Those intended for fundamental standards will be in straight tubes and will be refilled for each comparison, a mean value being obtained from a large number of fillings. Their true value will be determined from their dimensions and the mass of mercury which fills them, this mass being also determined from a large number of fillings.

This work is all done at the temperature of melting ice, in order to avoid large corrections, for the temperature-coefficient of mercury is nearly one-tenth of one per cent. The practical determination of the ohm from the legal definition can be made with an accuracy of about .001 of one per cent. Since the best absolute determinations of resistance by the Lorenz method are not reliable to more than .01 of one per cent., the definition fixes the ohm much more closely than its value in absolute units is known.

Mercury resistances intended for secondary standards will be made of W or U-shaped tubes. Their values will be determined, not from mass and linear dimensions, but by comparison with fundamental standards. They will be left set up for long periods of time, and the comparison repeated at intervals. The glass used in these standards will be subject to the same changes which occur in thermometers, and it will be necessary to investigate the extent of this effect upon the resistance of the mercury column.

The objection to a coil of wire for a fundamental standard is that it is not reproducible, and moreover, no material has yet been found which can be used in this form without change. By

*W. Jaeger. Zeitschrift für Instrumentenkunde 16 p. 134 (1896); Jaeger and Kahle. L. c. 21 p. 1 (1901); Report of British Association meeting for 1903; give descriptions of the work done in Germany and England.

using a number of coils and intercomparing them frequently, sudden or large changes in any one of them can easily be detected; but if all change gradually in the same direction there is no check. This is very apt to be the case if they are made of the same material. It is true that many wire coils have been constructed which have changed in the course of several years by no more than the uncertainty in the value of a mercury ohm, namely, about .001%, but one could not be sure of this except by reverting occasionally to the mercury unit. When mercury units are set up for long periods they decrease in resistance; with wire coils the change is more apt to be the other way, and they form excellent checks upon one another.

For a working standard a mercury resistance is not at all suitable, as it is very inconvenient to work, and the temperature must be controlled within .01° C. Wire coils are in consequence invariably used for every-day work. The choice of a material for these standards involves two considerations. In the first place, the greatest attainable constancy is required, and, secondly, facility in use must be considered. The last point will be met by a material having a temperature-coëffiicient and a thermo-electromotive force against copper as small as possible. For the absence of either of these properties will introduce difficulty and perhaps error in the measurement of the resistance. Copper is quite universally used for connecting wires and for galvanometer coils, and is moreover highly desirable for terminal lugs, etc., on account of its high conductivity. Any differences of temperature in the different parts of the Wheatstone bridge or other comparing apparatus will produce electro-motive forces to disturb the balance. The allowable differences in temperature are evidently inversely as the thermo-electric power of the metals used. Again, the larger the temperature-coëfficients of the coils used, the more exactly the temperature must be determined in order to attain a given accuracy in the result.

The alloy which best satisfies the above conditions is manganin, when properly treated before use. This alloy consists of

Copper	84%
Manganese	12%
Nickel	4%

After a coil is wound, but before final adjustment, it is baked from fifteen to twenty-four hours at a temperature of 140° C. and then aged. This treatment has the results of producing a coil which remains fairly constant. In making an exact adjustment, the low thermo-electric power of manganin, and the low temperature-coëfficient, greatly facilitate the work.

The temperature-coëfficient manganin wire varies in different specimens from zero to .00002. The coëfficient for the sheet metal used in low-resistance standards is sometimes positive and sometimes negative and runs as high as .00005. The thermo-electric power with copper is about one microvolt per degree Centigrade.

Other alloys exist which have a temperature-coëfficient as low as manganin, but they all have a higher thermo-electric power referred to copper. Thus for constantin, this is approximately forty microvolts per degree Centigrade. The alloys previously used for resistance standards, such as german silver, platinoid and platinum-silver, have temperature-coëfficients not less than .00022, or from ten to twenty times that of manganin. If resistance comparisons are to be made to one part in a million, this requires that the temperature of the coil should be known to less than 0.005° C. and be kept constant within the same limit, a condition impossible to fulfill under ordinary working conditions. If the tmeperature be known and controlled to the nearest 0.01° C., the comparison may be made to within a few parts in a million; but even this is difficult with any but the most exceptional facilities, and was rendered especially inconvenient by the practice of surrounding the coil with paraffin wax, as in the British Association type of coil. If the temperature be known only to .1° the resistance is uncertain by several hundred-thousandths, which is inadequate for precision-work.

The resistance of a manganin coil may be expressed in the form

$$R_t = R_{20} [1 + \alpha (t-20) - \beta (t-20)^2]$$

Twenty degrees Centigrade is a normal value for the temperature of a working-room, and coils are usually adjusted for that temperature. The linear coëfficient is the one which has already been referred to. The quadratic coëfficient β may usually be taken

as 0.0000004 and always lies between 0.0000003 and 0.0000006. The quadratic term is thus of secondary importance for small ranges of temperature, but in the course of ten or twenty degrees may outweigh the linear coëfficient. As this term is always negative, this means that the resistance attains a maximum with increasing temperature, this maximum usually falling near 30°, as may be seen by equating the derivative of the above equation to zero

$$\frac{dR_t}{dt} = R_{20}\left[\alpha - 2\beta(t\text{-}20)\right] = 0$$

$$\alpha = 2\beta(t\text{-}20)$$

$$t = \frac{\alpha}{2\beta} + 20$$

If α be negative, as in some of the sheet manganin, it merely indicates that the maximum lies below 20°.

That the last term of the equation may not be neglected was well illustrated in a case which has recently come to our attention. Coil No. 4086, made by Valder Bros., of London, and used by Prof. Barnes at Montreal in his calorimetric work, was sent to the Bureau for verification. This coil had previously been compared with others, both at Montreal and in England, and very discordant results obtained for its temperature-coëfficient. This led Prof. Callender* to suggest the idea of a hysteretic effect, or lag of resistance behind temperature, and to condemn manganin on that account. The resistance found for this coil at the Bureau of Standards was

$$R_t = R_{20}\left[1 + 17.4 \times 10^{-6}(t\text{-}20) - .61 \times 10^{-6}(t\text{-}20)^2\right]$$

β has here a very large value, and if a linear coëfficient be assumed, its value will appear decidedly different according to the temperatures used in determining it.

Substituting in the equation

$$\frac{dR}{dt} = R_{20}\left[\alpha - 2\beta(t\text{-}20)\right]$$

we have for the rate of change at 12° 27 microhms per °C.: rate of change at 25° microhms per °C. It is to be remembered moreover, that unless manganin is very carefully treated in its preparation, comparatively large changes take place in its resistance

*Trans. Royal Society 199 p 77 (1902).

in a short time. This results especially from insufficient annealing. It seems quite evident that coil No. 4086 has changed several hundredths of one per cent. since it was certified by Prof. Glazebrook in England in 1893, and as the measurements upon which Prof. Callender's conclusions were based extended over a period of more than one year, it is probable that the changes were still continuing. I have examined this coil for a lag of resistance behind temperature, but can find no effect of the order of magnitude claimed by Prof. Callender.

When manganin wire of large size is properly annealed and aged before use, the constancy of resistance of the coils is quite satisfactory. Of the one-ohm coils at the Bureau of Standards only one[1] has changed more than .005 of 1% and the average is much smaller than this. The variations found at the Reichsanstalt[2] are of the same order of magnitude. With coils of high resistance wound with fine wire the constancy is not so good. The fine wire is drawn cold and annealing produces a greater change in it, the resistance being decreased. Afterwards it seems to recover slightly and the resistance increases slowly for several years. In coils of 1,000, 10,000 and 100,000 ohms, changes as great as .07% have been observed in one year, and fine coils of these denominations at the Bureau of Standards have averaged .03% per year. It is desirable that some better treatment than the present process of annealing be found for these coils.

The low resistance standards of sheet metal were formerly made 0.1 mm. thick. These were found to change considerably, and a thickness of 1 mm. is now used, with the result that these standards are nearly as constant as the heavy wire standards. The changes in the course of years usually only amount to several thousandths of one per cent., although a change of .01% in 2½ years has been observed at the Reichsanstalt. When these low resistances are used as current standards and repeatedly loaded with heavy currents, the changes are greater.

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1. Excluding several coils which were accidentally overheated and thus had their resistances abnormally decreased. These are slowly recovering.

2. Jaeger and Lindeck. Zeit. f. Instrumentenkunde 18 p. 97 (1898).

Standard coils of the Reichsanstalt type are wound with manganin wire upon a hollow brass cylinder covered with a layer of silk and thoroughly shellacked. The ends are silver-soldered to copper terminal blocks. These in turn are both soldered and screwed to the heavy copper lugs which form at the same time both terminals and supports. Free access and circulation is allowed to the oil in which they are immersed by the holes at top and bottom of the casing.

Resistance of value less than .1 ohm are supplied with separate potential terminals and are made of sheet metal instead of wire.

[Standard resistances of value 1 ohm and .0001 ohm of the Reichsanstalt type were exhibited; also a 1 ohm coil of the B. A. type, loaned by the Western University of Pennsylvania. The other apparatus exhibited consisted of 10 ohm ratio-coils, provided with interpolation; .0001 ohm water-cooled resistance standard for current measurement; set of apparatus for comparing standard coils by the Kelvin double bridge method (loaned by Columbian University); Kelvin double-bridge box for comparison of low resistances; Mercury contact Wheatitone bridge box.]

The resistance standards at present in use by the Bureau are made of manganin wire, are of the Reichsanstalt pattern, and were furnished by Otto Wolff in Berlin. Their values are based on determinations made at the Physikalisch-Technische Reichsanstalt, and a number of coils are sent there each year in order to keep a check on the changes. Relative changes are easily determined by the inter-comparisons frequently made at the Bureau of Standards. There are at the Bureau ten one-ohm coils, and of each decimal multiple and sub-multiple, from .0001 ohm to 100,000 ohms, at least four. Coils of value .00001 ohm are now being constructed. Two coils of each set of four are used for working standards; the other two are used only to compare with these. There are also a number of coils of intermediate values, notably 2, 3 and 5 ohms, which are especially useful in stepping up from 1 to 10 ohms. After the values of the 10-ohm coils have been determined in terms of the 1-ohm coils, it is then easy by using a ratio of ten to one in the bridge ohms to step up to any decimal multiple or down to any decimal sub-multiple.

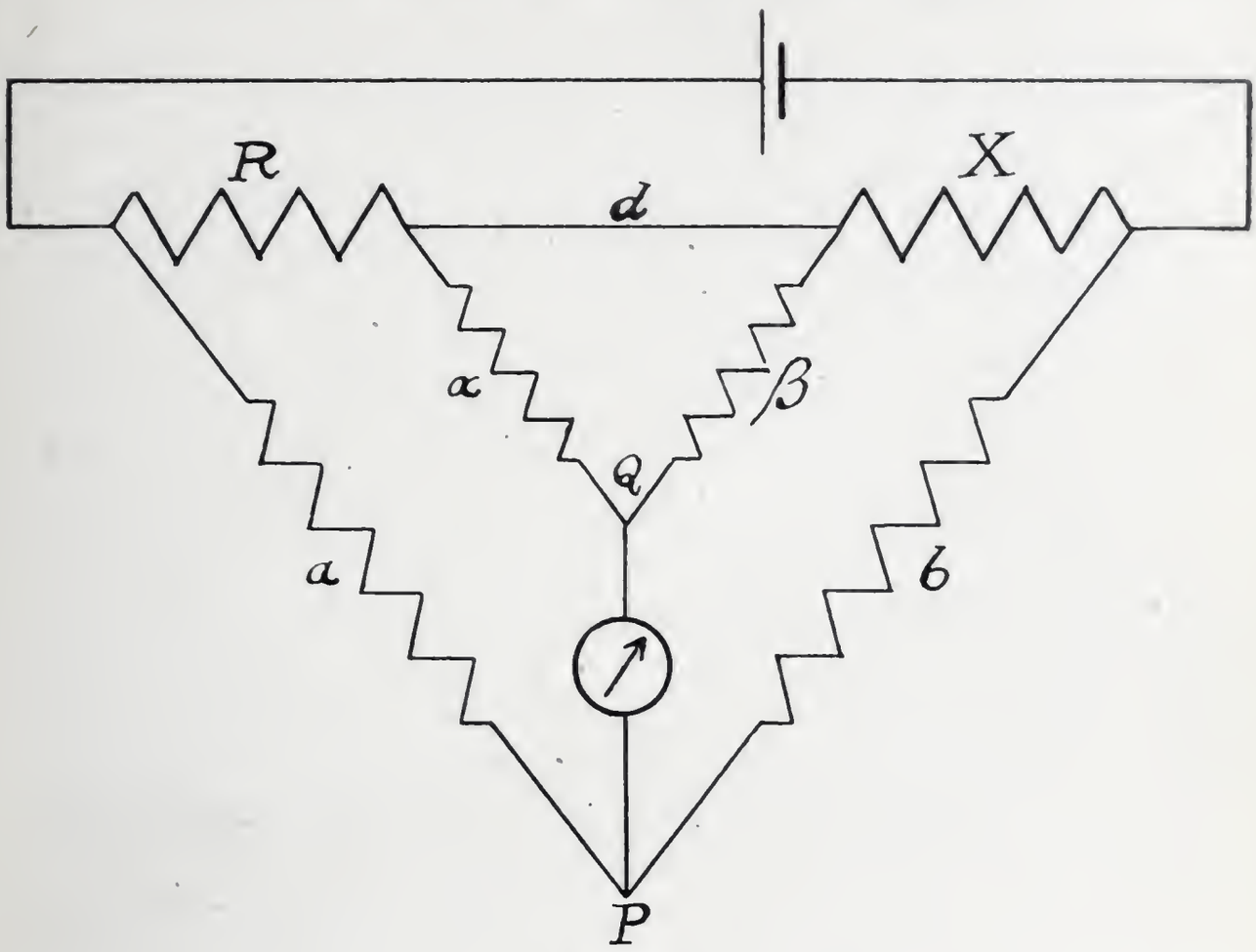


Figure 1.

The best method of comparing low resistances is by the use of the Kelvin double bridge. Since this is not in such general use as it deserves, we will consider it in detail. The bridge is shown in diagram in Fig. 1. It differs from the ordinary Wheatstone bridge in having an auxiliary pair of ratio coils shunted around the conductor connecting the two resistances under comparison, and the galvanometer is connected between these two coils. The effect is to exclude all connecting resistance from the values compared. This is best seen by deriving the equation for the condition that no current shall flow through the galvanometer. I take this derivation substantially from the original source.[3]

Let R and X be the coils to be compared.
" a " b be the main ratio-coils.
" α " β be the auxiliary ratio-coils.
" C = combined resistance in parallel of d and + B.
" E = difference of potential between A and B.
" P = " " " " A " point P.
" Q = " " " " A " " Q.

3. W. Thomson. Philosophical Magazine 24 p. 149 (1862).

$$\text{Then } P = E \frac{a}{a \times b}$$

$$Q = E \frac{R \times C \frac{\alpha}{\alpha \times \beta}}{R \times C \times X}$$

$$Q - P = \frac{E}{R \times C \times X} \left[\frac{R\,b}{a \times b} - \frac{X\,a}{a \times b} + C \left(\frac{\alpha}{\alpha \times \beta} - \frac{a}{a \times b}\right)\right]$$

This will be zero when there is no deflection of the galvanometer, hence

$$X = R \frac{b}{a} + C \left(\frac{\alpha}{\alpha \times \beta} \cdot \frac{a \times b}{a} - 1\right)$$

$$\text{or since } C = d \frac{\alpha \times \beta}{\alpha \times \beta \times d}$$

$$X = R \frac{b}{a} \left[1 + \frac{d}{R} \cdot \frac{\alpha}{\alpha \times \beta \times d} \left(1 - \frac{a}{b} \frac{\beta}{\alpha}\right)\right]$$

There are two cases in which this reduces to the simple relation $X = R \frac{b}{a}$

If the connecting resistance *d* could be made zero, we have one case.

Secondly, if $\frac{\alpha}{\beta} = \frac{a}{b}$ the same result is obtained, regardless of *d*. This means that the auxiliary ratio-coils must be in exactly the same ratio as the main ratio-coils. In that case, the coils under comparison are also in the same ratio.

This indicates a method of procedure in making a comparison. Keep the ratios $\frac{a}{b}$ and $\frac{\alpha}{\beta}$ always equal, and alter them simultaneously until a balance is obtained. Then

$$\frac{X}{R} = \frac{b}{a} = \frac{\beta}{\alpha}$$

This has been applied practically by D. Wolff, of Berlin, who has put on the market a bridge-box of this type, in which the main and auxiliary ratio-coils are always equal and can only be altered simultaneously. There are four dials, which are set so as to give no deflection in the galvanometer, and four significant figures may then be read off. This is especially useful in comparing resistances which do not bear a simple ratio, such as ammeter-shunts with a standard resistance.

To return to our equation. The term

$$\frac{d}{R} \cdot \frac{\alpha}{\alpha \times \beta \times d} \left(1 - \frac{a}{b} \frac{\beta}{\alpha}\right)$$

may be regarded as a correction term, since its value should always be small compared to unity. $\frac{\alpha}{\alpha \times \beta \times d}$ is less than one, and since $\frac{\alpha}{\beta}$ is chosen as nearly $\frac{a}{b}$ as m y be, the factor $\left(1 - \frac{a}{b} \frac{\beta}{\alpha}\right)$ is always quite small. *d* should always be made as small as pos-

sible by making the connection of stout copper, and can easily be made less than .001Ω when necessary. Thus for comparing resistances down to .01Ω the correction term can easily be made negligible. For smaller resistances it is necessary to consider and apply it in work of high accuracy. Thus if d=200 microhms, $b = a$, $\beta = \alpha\ (1-.0001)$ and R=.01 ohm, the correction only changes the result by one part in a million; but if R=.0001 ohm, the effect is 100 times as great, and would constitute a serious error if not considered. The ratio-coils are here assumed to differ by only .01 of 1%.

The correction term may be allowed for in several ways.[4]

First. a b α β are known or are determined by separate measurements. The ratio $\frac{d}{R}$ is easily determined by breaking the circuit through the auxiliary coils, and measuring with a milli volt-meter or galvanometer the fall of potential in each while the main current is flowing. The correction may then be calculated.

Second. Alter the auxiliary ratio by a definite amount and observe the deflection produced.

Knowing the values of α β a b, calculate how much the known inequality of $\frac{\alpha}{\beta}$ from $\frac{a}{b}$ would have changed the deflection on the main reading. This obviates the measurement of *d*.

Third. Since *d* is negligible compared to $\alpha + \beta$; and since R and X are very small compared to α and β and in approximately the same ratio, we may without sensible error write $\frac{X \times \beta}{R \times \alpha}$ for $\frac{\beta}{\alpha}$; thus getting the equation in the form

$$X = R\,\frac{b}{a}\left(1 + \frac{d}{R} - \frac{x}{x \times \beta} - S\right)$$

$$\text{where } S = 1 - \frac{a}{b} - \frac{X \times \beta}{R \times \alpha}$$

To determine S the connection *d* is broken, leaving an ordinary Wheatstone bridge with arms a, b, $X+\beta$ and $R+\alpha$. $\frac{d}{R}$ is determined as above.

A modification of this is to balance the bridge with the connection *d* in place. Then remove *d*, and shunt one of the auxiliary coils until the balance is sufficiently close. *d* is then replaced and the final readings taken, or, if necessary, a second approximation

4. Jaeger, Lindeck and Diesselhorst. Zeits. f. Instr. 23 p. 33 (1903). Translation to appear in Electrical Review, Jan., 1904.

may be made. Since the bridge is balanced with d removed, S=o and the correction disappears. This modification is due to Dr. F. A. Wolff and is analogous to obtaining a perfect balance on an ordinary Wheatstone bridge instead of obtaining an approximate balance and interpolating for the exact value.

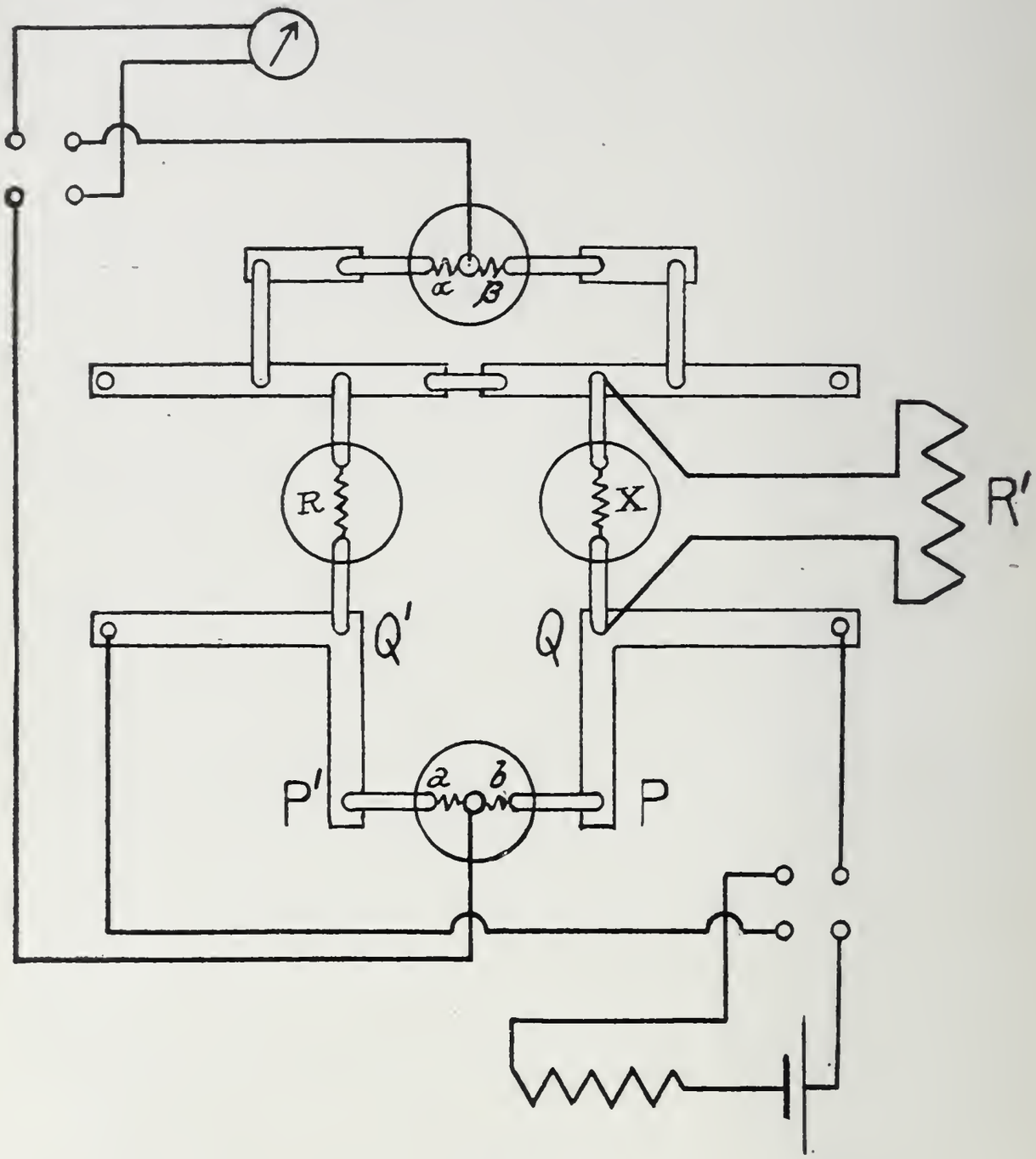


Figure 2.

In comparing standard coils they are joined by copper forgings 1.5 cm. thick and 2 cm. wide (see Fig. 2). These rest upon ebonite frames which give hight insulation. The coils are suspended from their terminals, which rest in mercury-cups in the copper forgings. The copper has a resistance of about 0.6

microhm per unit of length. The entire group of coils is immersed in a bath of kerosene in a tank about 50 cm. square and 25 cm. deep. This is provided with a steries operated by an electric motor, so that a uniform temperature may be maintained throughout the bath. When it is desired to have the coils under comparison at different temperatures, individual baths are brought up around the coils.

The galvanometer used is of Thomson astatic reflecting form, of high sensibility. When comparing one-ohm coils this indicates a difference of one part in ten million. Cement is supplied by storage cells, the cement-strength being limited by the consideration that the watts expended in a wire coil should be less than one-twentieth. If this value be exceeded, the temperature becomes appreciably higher than that of the surrounding bath, and it can not be accurately determined.

In making a measurement, a shunt R^1 is applied to the larger of the two coils being compared, and its value adjusted until an approximate balance is obtained. An ordinary resistance box answers very well for this purpose, and the value of the shunt need not be known with very great accuracy. Thus if a one-ohm coil be shunted with 10,000 ohms, an error in the shunt of 1% affects the result by only one part in one million.

Readings of the galvanometer deflection are taken for both positions of the battery commutator. The ratio-coils are then interchanged and the readings repeated. Next one arm of the bridge is changed by a definite amount, 0.1% or 0.01%, and the deflections again noted. This change can be made by shunting one of the arms of the bridge, or when the ratio-coils are provided with interpolatum, it is only necessary to shift the contact. The difference between this observation and the preceding one gives the deflection produced by a given change in the bridge. We can then calculate what change is necessary to reduce the average of the previous deflections to zero, i. e., to bring the bridge to a perfect balance, if the ratio-coils were equal. The result so obtained cannot be accepted until allowance is made for the resistance between the ratio-coil and the adjacent arm, since it really forms part of the ratio arm. The value of this connection can be determined by shifting the bat-

tery lead to the point P, and taking another observation. This throws P Q from one arm of the bridge to the adjacent one and the change produced must be divided between the two arms in inverse proportion to their values. In comparing coils of the same denomination, this correction disappears, since $P\,Q = P'Q'$ within the limits of accuracy; but with unequal ratio-coils the correction must be considered.

The accuracy attainable by this apparatus may be judged by the following set of readings, made for the inter-comparison of four 10-ohm coils. Each coil was compared with every other one, making six comparisons in all. The observed differences have been reduced to 20° C. by using the known temperature coëfficient of the coils. The numbers given are parts in a million:

No.	Obs. reduced to 20°.	Calc.	Obs. Calc.
1005—1006	+ 24.7	+ 24.7	0.0
1005—1398	— 24.0	— 23.4	— 0.6
1005—1399	— 6.0	— 6.5	+ 0.5
1006—1398	— 47.8	— 48.1	+ 0.3
1006—1399	— 31.3	— 31.2	— 0.1
1398—1399	+ 16.7	+ 16.9	— 0.2

When coils of high resistance are being compared, the resistance of the connections becomes negligible and the auxiliary ratio-coils are omitted. Adjustment for a balance may in this case be made by introducing additional known resistance in series with the lesser coil.

When the coils to be compared are provided with potential terminals, they are arranged as shown in Fig. 3.

In this case an approximate balance is obtained by shunting one of the main ratio-coils. The link L is then removed and one of the auxiliary ratio-coils shunted until the deflection of the galvanometer is negligible. This link is then replaced and the readings taken much the same as before. R′ and R″ are the shunting resistances. A is an ammeter, the test current being controlled by a rheostat B.

The actual ratio arms in this case include the potential terminals to the junctions of the actual resistances R and X. These connections are not interchanged with the ratio arms, and allow-

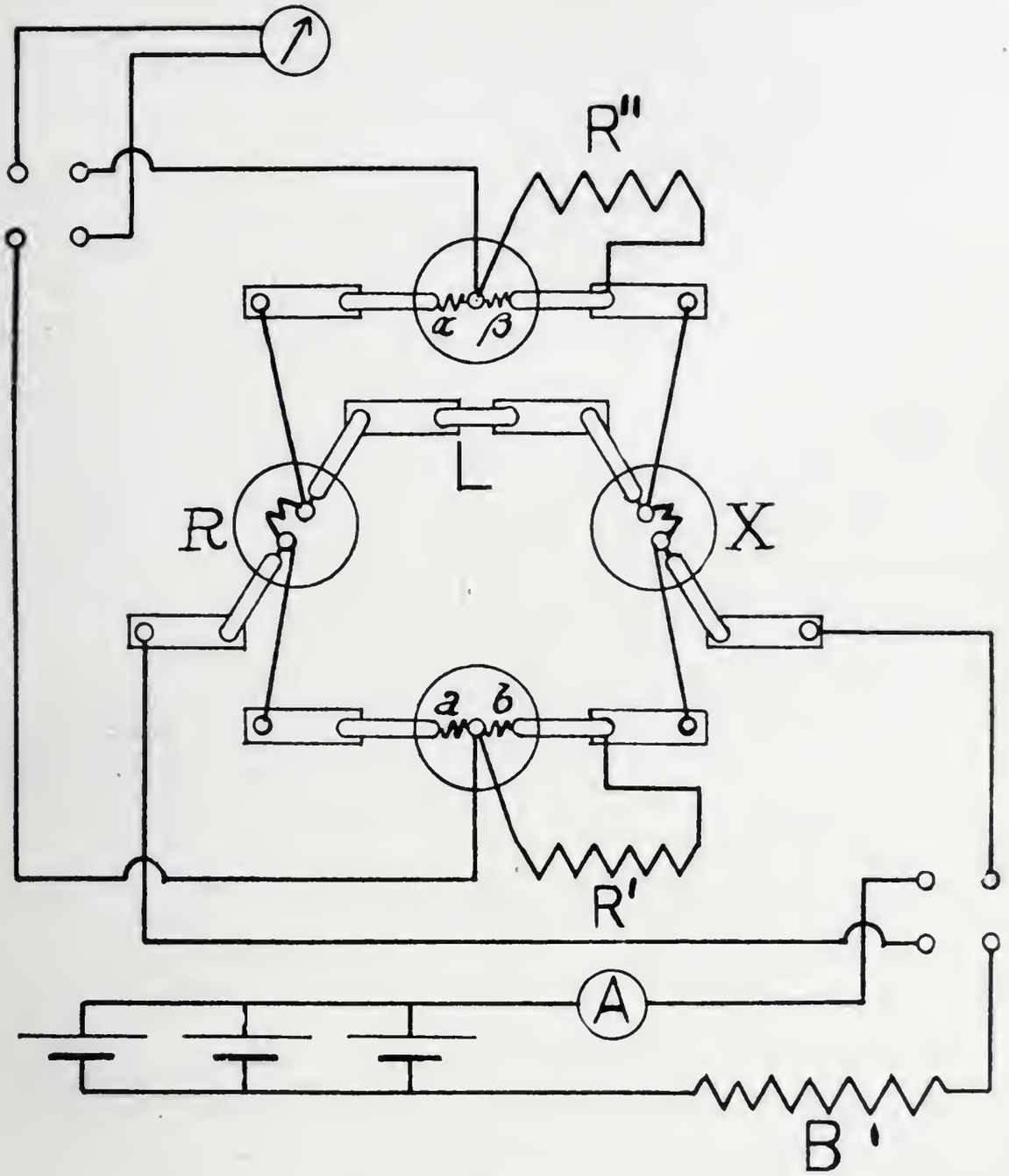


Figure 3.

ance must be made for them. This is best done by shifting a battery terminal as mentioned above, with the link L removed, observing the deflection before and after, and then determining the sensibility.

The Carey Foster method is well known, as it has been used very widely in this country and in England. It is an excellent method for resistances larger than one ohm, where a mercury contact and heavy connecting resistances become negligible. But it cannot be used with coils having potential terminals and hence is unsuited for comparing low resistances. For the entire resist-

ance up to the mercury cup must be used in interchanging the coils under comparison, and usually, too, there is no provision for eliminating inequality in the resistances between commutator and the terminals of the coils.

A bridge of this kind, of improved design, is now being constructed for the Bureau by the Western Electrical Instrument Company.

I shall not stop to discuss the differential-galvanometer method of comparing resistances, as it has not as yet been used at the Bureau of Standards, although in England and Germany it has been used for precise measurements with good results.

For calibrating resistance-boxes, Wheatstone, bridge sets, potentiometers, etc., comparisons are made on a Wheatstone bridge, which is supplied with mercury contacts and is used with the coils immersed in oil. Several such boxes are in use at the Bureau of Standards. One of these is of the Anthony form, designed by Dr. Wolff, with ten coils of each decimal denomination. The others have the usual arrangements of coils for a bridge with slight modifications. I have brought with me a bridge set designed by Dr. C. W. Waidner, of the Bureau of Standards, for use in platinum thermometry and constructed by the Leeds and Northrup Co., of Philadelphia, as those in use in the Electrical division could not be spared at this time.

The Bureau is now prepared to verify resistance standards of values 0.00001 ohm to 100,000 ohms and determine temperature coëfficients of same, as well as resistance boxes, ratio-coils, potentiometers, etc.

ELECTRO-MOTIVE FORCE.

In conformity with Act of Congress, the Clark cell is used as the standard of electro-motive force and its value is taken to be 1.4340 volts at 15° C. The Clark cell consists of Hg., as the positive pole, in contact with mercurous sulphate, and zinc as the negative pole in contact with sulphate of zinc, both sulphates being present in the form of paste or a saturated aqueous solution.

The Clark cell is by no means ideal. It has a temperature-coëfficient 0.00119 volt per degree centigrade, which necessitates an accurate knowledge of its temperature, since a change of .1°

effects it by nearly one part in ten thousand. Its electro-motive force lags behind the temperature, so that the temperature must not only be accurately known, but must be maintained constant for some hours before a measurement is made. Moreover, the glass cells have shown a tendency to crack at the point where the platinum wire is led into the amalgam.

The first two objections are grounded in the fact that the solubility of zinc sulphate changes rapidly with temperature, and that the cell is defined by a saturated solution. Prof. Carhart sought to overcome this by using an unsaturated solution, without excess of solid zinc sulphate. He thus succeeded in reducing the temperature-coëfficient to .00056 volts per degree centigrade, or about one-half.

This cell is to that extent preferable to the Clark cell as a working standard, but in cell using an unsaturated solution is suitable for a primary standard, since it cannot be reproduced with sufficient accuracy.

The only other cell which at present claims notice as a standard is the codenium cell, proposed by Edward Weston. This differs from the Clark cell in having codenium amalgam in place of the zinc amalgam, and codenium sulphate in place of zinc sulphate. The solubility of codenium sulphate varies very slowly with the temperature, with the result that the temperature-coëfficient for a cell with saturated solution is only .000038. A tenth of one degree change in temperature only changes the E. M. F. by a few microvolts. The breakage of the cell at the point where the electrode is sealed in has not been noticed with this cell. It thus shows itself superior to the Clark cell as a standard, for in constancy and reproducibility the two are equal. It should be noted here that for constancy of results the codenium should be used in amalgam in proportion of 6-14% as outside of these limits the E. M. F. will be altered. A 12-13% amalgam is usually used.

The cell placed on the market by the Weston Electrical Instrument Co., and known as the Weston cell, contains a solution of cadmium sulphate, which is saturated at about 4° C. and has a temperature-coëfficient which is almost entirely negligible, since

it is less than .00001. This cell forms an excellent working standard, and is used as such at the Bureau of Standards, after being calibrated by comparison with a Clark cell.

For the comparison of cells, as well as for the measurement of constant voltages of all kinds, the compensation method of Poggendorf, as applied in the modern potentiometer, is the best. Several forms of potentiometers are in use at the Bureau of Standards, the main points of which I shall briefly describe.

The early form of potentiometer, using a wire and sliding contact, was entirely unsuited for work of high accuracy. By using two resistance boxes in place of the two parts of the wire, and increasing one by the same amount that the other is decreased, the same principle may be applied with greater accuracy and is still in use in many places. It is far surpassed, in both accuracy and convenience, by the modern forms of potentiometer.

This potentiometer, diagrammatically illustrated in Fig. 4, was proposed by Prof. Feusseur and is made by O. Wolff, of Berlin.[5]

The two main dials are made up of coils having resistances of 1,000 ohm and 100 ohm respectively. There are 14 coils in the one dial and 9 in the other. The circuit containing the galvanometer and standard cell or unknown E. M. F. is connected to the battery circuit at points determined by the position of the contact-brushes on these dials. Between these there are three intermediate dials, on each of which there are two pairs of contacts and two sets of coils, of equal value, 10 ohms, 1 ohm, and .1 ohm respectively. Each dial is arranged and connected so that for any position of the handle controlling the contact-brushes there are always ten coils in the battery circuit,, while the number included between the terminals of the galvanometer circuit is fixed by the position of the contact and may be varied from zero to nine. By using all the dials the resistance between the terminals of the galvanometer circuit may be varied from .1 ohm to 14999.9 ohms by steps of .1 ohm while the resistance in the battery circuit remains unchanged. A

5. The mechanical details are described in Zeit. f. Instrumentenkunde 21 p. 227 (1901).

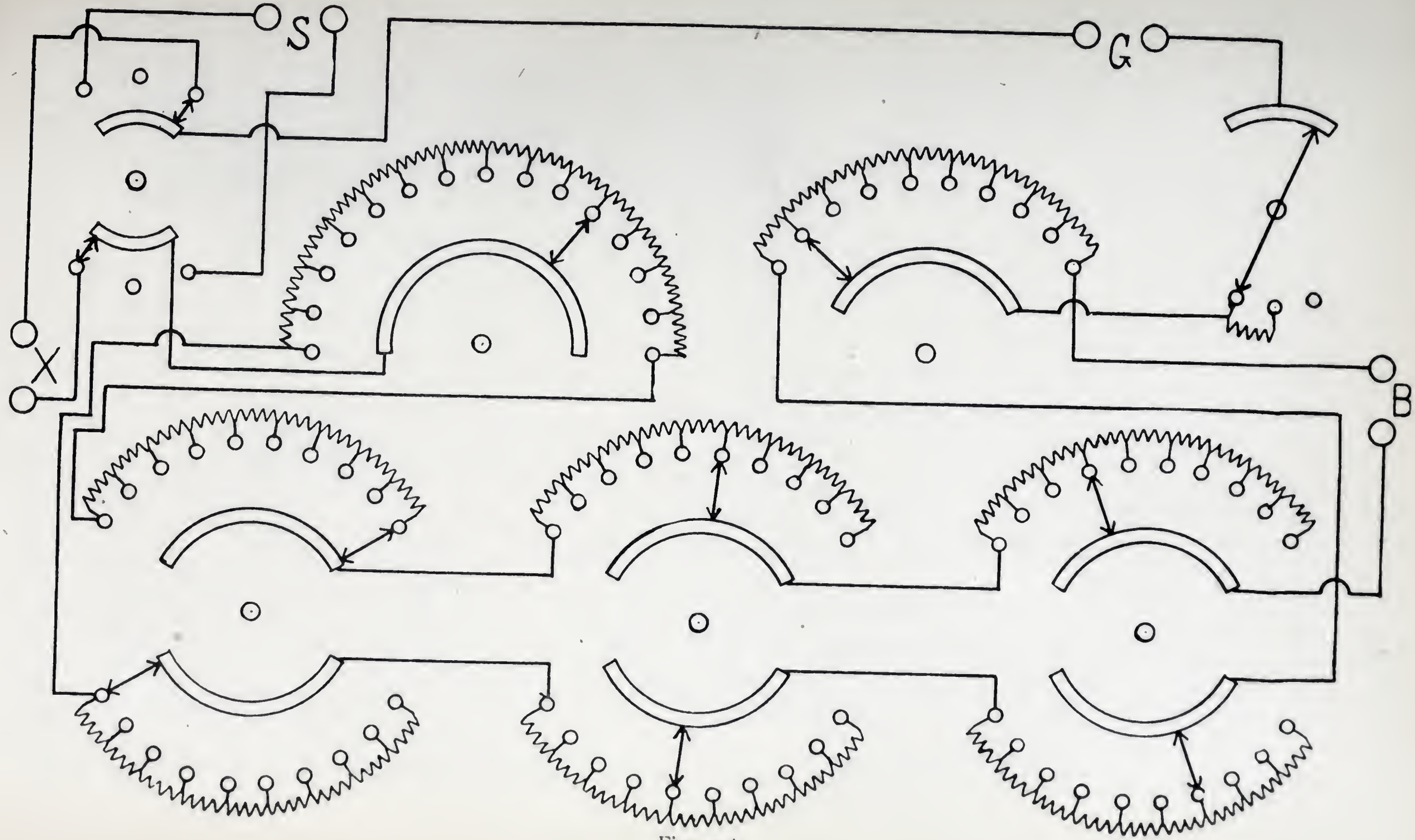


Figure 4.

steady current of .0001 ampere is supplied by a storage battery or other constant source, and is regulated by an external resistance in the battery circuit. The current is adjusted by setting the dials for a resistance $= \frac{\text{E. M. F. of std cell}}{.0001}$ and altering the regulating rheostat until no deflection is obtained on closing the galvanometer key. Thus if a Clark cell at 15° C. were being used as a standard, the setting would be for 14340.0 ohms. After adjusting the current to its proper value, the unknown E. M. F. is switched into the galvanometer circuit and the dials adjusted for balance. When this is obtained the voltage may be read off directly from the resistance of the dials by properly shifting the decimal point. The instrument may be used in this way for measuring voltages up to 1.50 V. The range may be increased ten times by using a current of .001 ampere. The current would then be adjusted for the Clark cell to balance on 1434 ohms.

Most of the modern forms of potentiometer, however, make use of the Kelvin-Varley slide. This may be illustrated by the instrument made by The Leeds & Northrup Co., shown diagrammatically in Fig. 5. Here only two of the dials are in the battery circuit. One is made up of fifteen 1,000-ohm coils, the other of ten 10-ohm coils. Any one of the 1,000-ohm coils may be shunted by the lower left-hand dial, by moving the two sliding contacts to the proper position. These two contact-brushes are fastened rigidly together and moved by a single handle, and must always form a shunt to one of the coils. The shunt has a value of 9,000 ohms, since the lower dial consists of nine 1,000-ohm coils. The galvanometer circuit is connected through the contact piece to some point of this dial. If the battery current has a value of .0001 ampere, the fall of potential through each coil of the main dial is 0.1 volt, except the coil shunted, when the fall is 0.09 volts. The same fall of potential (.09 volt) takes place through the lower dial in shunt with it, the fall in each coil thereof being 0.01 volt. Hence, by shifting the contacts on these two dials, the potential at one end of the galvanometer circuit can be altered in steps of .01 volt up to 1.5 volt. The other dials are similarly arranged. The fall of potential through the other dial in the battery circuit is .001 volt per coil, except in the coil shunted by the next dial, where it is .00099 volt, or .0001 volt for each coil of

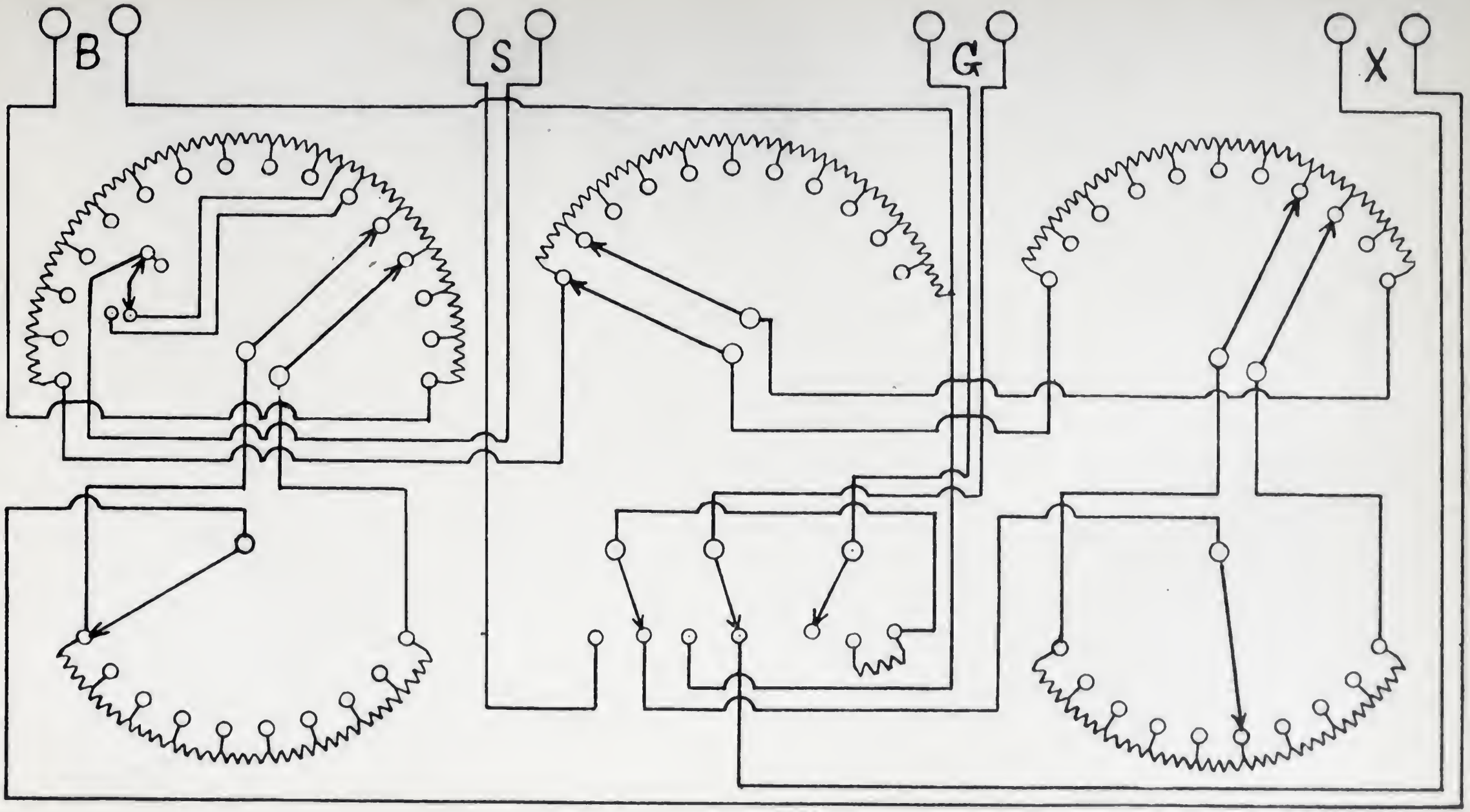


Figure 5.

the latter dial. For this dial consists of ten coils of 100 ohms each, one of which is shunted by the lower right-hand dial, consisting of nine coils of 100 ohms each. The fall of potential through the last named dial is .00009 volt, or .00001 volt for each coil. Since the other end of the galvanometer circuit (when X is in circuit) connects through the contact of this dial, it is seen that the fall of potential across the terminals of the galvanometer circuit can be adjusted to .00001 volt. The current is adjusted to .0001 ampere by switching the standard cell into the galvanometer circuit, and varying the current by means of an external rheostat until a balance is obtained. The potentiometer illustrated is made for a Weston cell having an E. M. F. of 1.01980 volt. It is connected across the first ten coils of the first dial (10,000 ohms) all the coils of the middle dial (99.9 ohms) and sufficient additional resistance in the battery circuit to give a total of 10,198 ohms. When the setting of the contacts on the first dial is less than 10,000, one of the coils is shunted, making the resistance up to that point only 9,900 ohms; when the setting is above 10,000 the shunted coil is not included; hence an automatic switch is provided to shift the point of connection for the standard cell by 100 ohms, and this switch is operated wherever the contact passes over the tenth coil. If a Clark standard cell be used the connection is across 14,340 ohms, with means for changing it to suit other temperatures than 15° C.

In the potentiometer of the Siemens & Holske firm, the standard cell is connected across a separate resistance, chosen from a set of 10,190, 1,019, 101.9 ohms, and the range of the apparatus thus increased ten or one hundred times. It is necessary that these resistances be very accurately adjusted.

Both of the arrangements just mentioned offer facilities for rapid work which are not possessed by the Wolff form. By simply throwing a switch, the galvanometer is put in circuit with the standard cell; and without adjusting the dials, the constancy of the battery current may be tested. In the Leeds form the cell is is connected across the same resistances as the E. M. F. to be measured, and changes in resistance of the coils, which often occur with time, do not affect the accuracy of measurements of electromotive forces of the same approximate value as that of the stand-

ard cell. In both forms corrections will usually have to be applied, where accuracy to .01% is required, owing to the fact that the cells used as secondary standards, if of the Weston or Carhart forms (i. e., with unsaturated solutions) will not always have the E. M. F. assumed in the design of the potentiometer. The Wolff potentiometer, on the other hand, permits the current to be adjusted with the standard cell at any position of the dials, and thus obviates any other corrections than that which may be due to inaccuracy in the adjustment of the resistances.

Moreover, any standard cell may be used with it, whereas, the other forms are arranged for a particular type of cell, and may be used with other types only with great inconvenience.

In measuring voltages of higher value, a volt-box may be used with any form of potentiometer. This consists of a resistance of one or more hundred thousand ohms to which the E. M. F. to be measured is applied. The fall of potential in a definite fraction of this resistance is measured in the usual manner on the potentiometer.

The Siemens and Holske potentiometer is arranged for measuring high voltages without the use of an auxiliary battery. The test-current is supplied by the source of high E. M. F. and passes through a high variable resistance, which must be accurately calibrated. This is adjusted until the current has a value of .0001, .001, or .01 ampere as determined by balancing the standard cell across one of the standard resistances previously mentioned. The value of the resistance required for a balance is a measure of the voltage.

With an accurate potentiometer and a sensitive galvanometer, electro-motive forces may be compared to one part in one hundred thousand.

The Bureau is now prepared to calibrate volt-meters and milli-volt-meters up to 300 volts, and this will shortly be raised to 2,000 volts, as a high voltage storage battery of small capacity has been purchased and will soon be set up. Thermal couples, standard cells, and direct electro-motive forces of whatever kind, not exceeding these figures in value, may be readily verified.

CURRENT.

Steps are now being taken by Dr. Guthe towards the construction of an absolute electro-dynamometer for the measurement of current. This will be used in connection with the silver voltometer for a verification of the electro-chemical equivalent of silver, and also in making a determination of the absolute value of the Clark and cadmium standard cells.

The value of the ampere is legally defined in terms of the electro-chemical equivalent of silver, but as the silver voltometer is not a convenient apparatus to use in every-day work, and since comparisons with it cannot be made to a degree of accuracy as high as that attained in the comparison of resistances and electro-motive forces, all measurements of current in the practical work of the Bureau of Standards are made in terms of resistance and electro-motive force. The method is to pass the current through an accurately known resistance, and measure the difference of potential at its terminals on the potentiometer. A current-carrying resistance standard for this purpose should possess the same general properties necessary in a resistance standard of precision; it should, moreover, be designed to carry a larger current and have facilities provided for the dissipation of the energy which is necessarily generated in it, so that the rise of temperature may not be great. I have brought with me such a resistance standard, made by O. Wolff, of Berlin. It has a resistance between the potential terminals of .0001 ohms and can safely carry 2,000 amperes. The resistance is composed of sheet manganin, which is screwed and soldered to heavy copper terminals. The manganin is in an oil bath which is cooled by a stream of water flowing through a coil of pipe, which is also in the bath. A stirrer is provided in the oil bath. This resistance is adjusted to within less than .001 of one per cent. of its nominal value at 20° C. (.000100000 ohms) and has a linear temperature-efficient of 16 microhms per degree.

Another Ammeter shunts can be compared with a standard resistance by the use of the Kelvin Double-Bridge Box, already described.

The Bureau is at present prepared to do direct current testing up to 1,000 amperes and in the new buildings now being com-

pleted facilities will be provided for obtaining 15,000 amperes. The current is supplied by four large storage cells of normal rate 100 amperes, and is regulated by a rheostat of special construction. The material is a low temp. alloy and the units have a resistance of about .04 ohm each. They may be thrown successively in parallel until the desired current is obtained. There are in all fifty units. For finer regulation and for currents less than fifty amperes a rheostat of lower capacity and higher resistance in parallel with the first, is used.

In testing indicating wattmeters, separate sources of current and voltage are used and each is measured on the potentiometer. In testing recording wattmeters, readings are taken either on an indicating wattmeter or with separate voltmeter and ammeter, all of which have been calibrated. The observer counts the turns of the disc of the instrument, and by making an electrical contact records the time upon a chronograph with revolving cylinder. An accurate chronometer, with break-circuits, marks seconds upon the same sheet and thus gives an accurate measure of the time.

CAPACITY.

The Bureau is supplied with mica condensers of the best makes in considerable quantity and is prepared to make comparisons with these when desired. Some of them are furnished with certificates from German Reichsanstalt and National Physical Laboratory of England. Some preliminary experiments have been made toward the absolute measure of these capacities, and an air-condenser is now being constructed for a standard. The many points to be investigated in connection with condensers, such as the dependence of capacity upon method and time of charge, the temperature-coëfficient, absorption, leakage, etc., will require considerable time for their solution.

INDUCTANCE.

Standards of self-inductance wound upon marble have been obtained, and a standard of mutual inductance, also to be wound upon marble, has been designed by Prof. Rosa, and is now being constructed. Standards of self-inductance, with certificates from the German Reichsanstalt and National Physical Laboratory may

be used for comparisons, but their values have not yet been determined absolutely at the Bureau of Standards. This work will be taken up as soon as possible.

ALTERNATING CURRENTS.

The work in alternating currents is largely in the preliminary stage. It has taken considerable time to get the necessary apparatus made and to plan the work. This has largely been done now, and as this division of the Bureau will be the first to move into the new Mechanical Laboratory, now almost completed, it will not be long before the Bureau is ready to test all kinds of A. C. instruments. A temporary laboratory has been in use for the past year, where the preliminary work in capacity, inductance, testing of indicating and recording wattmeters, electrometers, etc., has been done. It is provided with a 6 K. W. three-phase rotary converter, which is driven by direct current from a storage battery. Alternating current at 70 volts and 60 cycles is obtained from it, and an alternating generator direct connected to it gives 120 volts at 120 cycles. Another small single-phase alternator supplies 120 volts at 120 cycles. A large variety of transformers permit almost any desired voltage or current to be obtained.

In the new laboratory this will be supplemented by a twin generator and motor set. Each generator is 3-phase, 60 cycles, 120 volts, and their relative phase will be adjustable. These two generators will be used, with transformers, to supply the current and voltage for wattmeter testing, and the range will be up to 800 amperes. Any desired leading or lagging load may be artificially supplied by this set.

Another testing set will consist of a motor and two two-phase alternators, giving respectively 60 and 180 cycles at 125 volts. By connecting these two generators in series, and adjusting their relative phase and the voltages, a wide range of forms of wave may be secured, which will be useful in determining the effect of the wave-form upon indicating and recording instruments, a subject upon which very meager information is at present available.

The Bureau is now prepared to test indicating and recording wattmeters up to 250 amperes with alternating current, and this

range will soon be increased. Voltmeter- and ammeter-testing with A. C. is still in the experimental stage, and much investigation remains to be made. Some preliminary observations, using an electrometer as a stepping-stone from the direct-current standards to alternating current, indicate that a variety of commercial instruments, which read correctly with direct-current, are inaccurate on alternating current.

The laboratory is now supplied with Kelvin balances reading up to 600 amperes and 25 kilowatts, electrometers and electrostatic voltmeters up to several thousand volts, indicating wattmeters up to 100 amperes. Two wattmeters, frequency indicators, a curve tracer and a phase-meter have recently been constructed in the instrument-shop of the Bureau from designs by Dr. E. B. Rosa, which aim to avoid some of the errors of commercial instruments. These instruments are made astatic by having two suspended coils and two pairs of field coils, and the influence of stray fields, even when alternating, is largely eliminated. The field coils, for heavy current, are made of stranded conductors, so that the distribution of current may be the same on direct and alternating current. The frames are entirely wooden, so that eddy currents cannot be set up in them. These instruments have given very satisfactory results, and it is purposed to construct others of greater carrying capacity in the near future.

But until instruments built upon the dynamometer principle are shown to give the same results with alternating current as with direct-current, it cannot be assumed that they do; and even when there is no error from any other cause, it becomes necessary with wattmeters used for lagging and leading loads to apply a correction depending upon the difference in phase. It seems necessary to fall back, for a transition instrument connecting A. C. measurements with our fundamental electrical standards, to the electrometer, not only for measurements of voltage; for, by the use of standard resistances, the electrometers can be applied equally well to the measurement of current and power, and its indications are entirely independent of phase-differences.

The Bureau is in possession of a variety of electrometers, of which a few may be mentioned.

The Kelvin electrometer is of the multicellular quadrant form, is supplied with oil-cup for damping and is furnished with a variety of suspensions. Its greatest usefulness is in the neighborhood of 100 volts.

The Ebert & Hoffman instrument consists of two condenser plates, between which is suspended an ellipsoidal conductor. In the zero position its axis makes an angle of 45° with the plates. When the plates are charged there is a force urging it to rotate so that its axis will be parallel to the lines of electric force. This is resisted by a bifilar suspension. Damping is provided by a brass sphere, also hung from the suspension, which moves between the poles of a magnet. It is thus made aperiodic. Several thousand volts may be measured on this instrument, but it is not sensitive to small electro-motive forces.

The Hallwachs electrometer is a very useful form for small voltages. It is of the quadrant form with a single needle of aluminum foil. The suspension is a very fine platinum wire, which has shown itself free from elastic fatigue. Damping is by means of an air vane, which turns in a closed box with very little clearance, making it almost aperiodic. This box is connected through the suspension with the suspended system, so that it is at the same potential as the vane.

In the electrometer of Dolezalek, the dry pile formerly included in the suspended system has been abandoned, and the quartz suspension is made sufficiently conducting for static work by dipping it in a solution of a hygroscopic salt. For use with alternating currents of high frequency the quartz is silvered. The needle consists of paper coated with tin, and swings between the usual pairs of quadrants. Suspensions as small as .004 min. diameter may be used, and the instrument measures small fractions of a volt with facility.

DISCUSSION.

MR. SCOTT.—I have a general interest in this subject, as well as a special one. As was stated at the beginning of the paper, there has been some discrepancy between different standards, and some uncertainty in the past, and it is very gratifying to know

that the new National Bureau of Standards has taken up the electric work in the very thorough manner which has been shown here this evening. A good friend of mine, who occupied the chair adjacent to my own, and who is more of a mechanical turn of mind than electrical, has nudged me every little while when Dr. Lloyd made some reference to millionth parts in measurements, indicating evidently that this was something far more fanciful than practical. But it also shows the very high degree of precision to which electrical measurements can be carried, and that this work ranks with chemistry and the telescope, Mr. President, in the accuracy of results. It is rather striking, too, that the measurement of this unseen, invisible, intangible something which we call electricity can be carried to such definite limits, and while the apparatus shown here may, and in one way does, savor of the laboratory, and a high degree of refinement, yet it is withal a very simple kind of apparatus for measurements—commercial measurements of electricity; and it is notable, too, that electrical measuring instruments take a high place among instruments of measurement generally for their simplicity, their accuracy, and their ease of application.

Take, for example, the measurement of power. Mechanical power is in one way a very simple thing, since it consists simply in the measurement of force and the distance through which it moves. Take, for instance, the measurement of the engine—the power of the engine, and the measurement of the power given out by the engine to shafting, machinery, etc. These are all matters which need to be known very accurately by the Mechanical Engineer; but the measurement of power given out by an engine is not a matter of a very high degree of accuracy or refinement. The engine indicator is an instrument which must be in the hands of an expert to get results which are concordant, and even then the expert is satisfied if his results agree within more than one-millionth part.

Again the measurement of power conveyed by belting or shafting. There are various sorts of transmission dynamometers; but, so far as I know, none are convenient, simple, and reliable. But when an electric motor gets to work in a machine shop, then a little instrument which you can almost carry in your vest pocket

can be applied to that motor, and the power which the motor receives from the circuit can be measured with great ease and accuracy. Also variations in the power can be readily expressed. For instance, continuous readings can be taken of variations in power, or diagrams can be made for any length of time by very simple and reliable instruments. Measurements of this kind in the machine shop show just what power is required for lathes, planers, etc., and what they are taking in power from the main circuits, which condition has reacted on mechanical designs and the general lay-out of machine shops. Such a system of measurement is valuable, not only to the electrical engineer, as giving an insight into the fundamental power requirements in any works, but also to all those who have to do with the distribution of power.

The National Bureau of Standards is doing an excellent work in giving the manufacturers and to laboratories definite, accurate and reliable standards.

VICE-PRESIDENT.—Any further discussion.

MR. FISHER.—One thing is to be noted about what the Bureau is doing; and that is that they not only give us determinations of instruments which we choose to send them for that purpose, but they will also instruct us how these determinations should be made, and how the instruments should be used. I have been very much interested in that part of their work. Occasionally we send instruments to the Bureau, and have received many pointers which a person ordinarily would not think of. It seems to me they are filling a double field in this country, not only in giving us good determinations of instruments, but also in instructing us how to use them, and by sending representatives of the Bureau to different cities. Their representatives have been here a number of times. I wish to say that I have enjoyed the paper to-night and think it has been very instructive, and I am sure we all owe Dr. Lloyd a very hearty vote of thanks. I will make a motion to that effect.

(Motion carried.)

PROFESSOR KINTNER.—One part of Dr. Lloyd's paper which attracted my attention was where he spoke of the equipment of an alternating current laboratory, and particularly his reference to very high voltage—I believe he said one hundred thousand

volts. I would like to ask him as to just what kind of apparatus is used in this measurement of voltage and the degree of precision with which can be measured.

DR. LLOYD.—I had intended to say a little more about the precision of the work we do generally, but I will first answer the immediate question. I think I spoke of several thousand volts, however, and not so high as mentioned. We have a very satisfactory instrument in the form of an electrometer which we have just received. This electrometer consists of two large condenser plates, which have suspended between them an elipsoid of conducting material, which in its ordinary position has its longer axis making an angle of about 45 degrees with the condenser plates. When the plates are charged, an electric field is set up between them, giving the suspended elipsoid a tendency to motion. The reading is by telescope. I do not know whether I have made my description very clear.

(Dr. Lloyd illustrated his explanation more completely by drawings on the board, etc.)

This particular instrument is provided with a magnetic dampener, which makes it very satisfactory to work with. It can be read with accuracy to one-tenth of one per cent., which is all that is usually desired in indicating instruments.

In regard to the general precision of these measurements, I would like to say that comparisons can be made with far greater precision than absolute measurements can be made. Take, for example, the Lorenz method, which was formerly used to show absolute values of the ohm, which did not vary more than one one-hundredth per cent. By the use of the mercurial standard, we find this unit can be measured to about one one-thousandth per cent. That is by taking a large number of observations, and finding the mean, we can be certain of the mercurial unit to about one one-thousandth per cent. In fact, in measuring by comparison, we can get as near as one part in a million. We cannot reach so great precision in very high resistance nor in very low resistance.

In measurements of electro-motive force, comparisons can be made to one part in a hundred thousand without special difficulty, and in this case, too, comparisons can be carried to a much greater

distance than any absolute measurements. With the electro-dynamo meter the absolute measurement of current cannot be carried farther than one part in ten thousand, but we can make comparisons without difficulty to one part in one hundred thousand.

In such work as we do, it is highly desirable that accuracy be carried farther than absolutely required in commercial work. If commercial requirements are to within one-tenth per cent., then, of course, it is highly desirable that precision work be carried at least to one one-hundredth per cent., so that there may be a large margin of safety. In alternating current work, the accuracy is not so great. You cannot get a source of alternating current as steady as the direct current supplied from a storage battery. Moreover, instruments used in transforming from direct current do not give certainty or accuracy beyond about one per cent., so that we are limited in alternating current measurements to about that per cent., which is usually sufficient for all practical requirements.

MR. BARNSLEY.—I want to say that we are very anxious that the members of this Society shall come together and enjoy themselves, and I want to say before we adjourn that I very much hope you will all come to the steamer on Friday night, and in an enthusiastic mood, because the Committee has arranged for them to have a good time. I have said nothing heretofore in regard to the expense, and I might explain that this will be merely nominal. The boat leaves the wharf at the foot of Market Street at 8:15 P. M. sharp. I hope all members will be there and have one or two friends along who will help the good cause along.

A motion to adjourn was carried at 10:35 P. M.

C. W. RIDINGER, *Secretary.*

CHEMICAL SECTION.

PITTSBURGH, PA., September 23, 1903.

The regular monthly meeting of the Chemical Section was held in the rooms of the society. In the absence of the chairman, Vice-Chairman and Secretary Mr. A. G. McKenna and Mr. G. P. Maury were chosen chairman and secretary pro tem., respectively. Mr. Charles Johnston read his paper on "Bunsen's Method applied to the determination of Chromium in Iron, Steel, Ferrochrome and Chrome Ores." After general discussion, the section adjourned.

(Signed) C. P. MAURY, *Sec'y Pro Tem.*

STRUCTURAL SECTION.

A meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held at the Society's House, 410 Penn Ave., Pittsburg, Sept. 29, 1903.

The meeting was called to order at 8:25 P. M., sixteen members and visitors being present. Franz Engstron, Vice-Chairman, in the chair.

Minutes of the previous meeting were read and approved.

Discussion of the subject for the evening, "The Building Stones of Western Pennsylvania," was participated in by Geo. T. Barnsley, F. Z. Schellenberg, and others.

Subject selected for next meeting, "Timber Construction."

On motion, Section abjourned at 9:50 P. M.

WILLIS WHITED, *Secretary.*

STRUCTURAL SECTION.

A meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held at the Society's House, 410 Penn avenue, Pittsburg, October 27, 1903.

Meeting was called to order by the Secretary at 8:40 P. M., 11 members and visitors being present, neither the chairman nor vice-chairman being present. On motion Marshall W. Brown was elected temporary chairman.

Minutes of the previous meeting were read and approved.

Discussion of the subject for the evening, "Timber Construction," was participated in by Marshall W. Brown, W. C. Hawley, Willis Whited and others. A collection of samples of 27 species of timber, presented to the Society by J. J. T. Penney, of J. E. McIlvaine & Co., was received. Subject selected for next meeting, "Concrete Steel Construction."

On motion Section adjourned at 9:45 P. M.

WILLIS WHITED, *Secretary.*

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and thirty-eighth regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's House, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, October 20th, 1903, at 8:10 o'clock. First Vice President James M. Camp in the chair, and 108 members and visitors present.

The minutes of the preceding meeting were read and approved.

The Board of Directors reported that they had passed favorably on the following applications for membership and present same to the Society for action:

DAVID E. BROWN, - Mgr. Electric Supply Co. - { J. E. Whittlesey, J. F. Kuntz, L. P. Blum.
245 Third Ave., Pittsburg, Pa.,
h., 75-6 Kelly St., Pittsburg, Pa.

ASA LORD CANAVAN, - Draftsman, - { L. F. Hildner, F. S. Rice, Z. H. Sikes.
Riter-Conley Mfg. Co.
h., 1820 Davis Ave., Allegheny, Pa.

FRANCIS W. H. CLAY, - Counselor-at-Law, - { Wm. B. Hough, V. F. Holmes, C. W. Ridinger.
In Patent causes, etc.,
518 Frick Bldg., Pittsburg, Pa.

JOHN WM. CORDES, - Asst. Chief Engineer, - { Chas. Hazel, C. C. Stutz, S. Diescher.
Pittsburg Plate Glass Co.
h., 801 Fallowfield Ave., Charleroi, Pa.

JOHN J. CRANE, - Inspector, - { T. D. Lynch, B. B. Abry, S. M. Kintner.
Westinghouse Electric & Mfg. Co.
h., 165 Home St,, Pittsburg, Pa.

JOS. T. DONALDSON, - Civil Engineer, - { C. W. Coffin, F. S. Rice, F. M. Bowman.
Riter-Conley Mfg. Co., Pittsburg, Pa.
h., 1209 Resaca St., Allegheny, Pa.

WM. M. DRAVO, - American Window Glass Co. - { G. H. Neilson, Wm. Metcalf, S. Diescher.
Farmers Bank Building, Pittsburg, Pa.
h., Arnold, Pa.

THOS. D. GILLESPIE, , Auditor, - { H. M. Wilson, W. C. Coffin, F. M. Bowman.
Riter-Conley Mfg. Co., Pittsburg, Pa.
56 Water St , Pittsburg, Pa.

CECIL N. HAGGART, - Draftsman, - { J. K. Lyons, C. M. Canady, Willis Whited.
American Bridge Co.
h., 129 Roup St., Pittsburg, Pa.

RAYMOND D. HALL, Squad Master in Draft'g Room { L. F. Hildner, F. S Rice, H. M. Wilson.
Riter Conley Mfg. Co.
h., 825 Holland Ave., Pittsburg, Pa.

ANDREW G. HERR, - Draftsman, - { P. Brynn, H. Leacock, G. M. Shaw.
American Bridge Co.
51st St , Pittsburg, Pa.

CHAS. H. ISRAEL, - Chief Draftsman, - { G. E. Klingelhofer, C. A. Connelley, J. M. Camp.
American Foundry & Construction Co.
h., 594 Hazelwood Ave., Pittsburg, Pa.

W. L. KLINGELHOFER, - Sales Agent, - { W. E. Klingelhofer, C. B.Connelley, S. Diescher.
American Foundry & Construction Co.
h., 3321 Ward St., Pittsburg, Pa.

WARREN MITCHELL, - Engineer, - { W. T. Wallace, T. F. Wolf, S. Diescher.
Penn Gas Coal Co.,
h., Irwin, Pa.

HUGH MUNRO, - Mechanical Engineer, . { E. L. Messler, Wm. Smith, R. B. Kernohan.
Eliza Furnaces, Jones & Laughlins, Ltd.
Box, 625 Pittsburg. Pa.

STANLEY C. REESE, - Mechanical Engineer, . { J. S. Martin, A. J. Taylor, F. S. Rice.
Riter-Conley Mfg. Co.
h., 216 N. Lang Ave., E. E., Pittsburg, Pa.

WALTER S. SMITH, - Engineer, - { W. M. Judd, J. F. Kuntz, C. J. Coon.
W. G. Wilkins Eng. Co.,
h.. 1006 Cedar Ave,, Allegheny, Pa.,

MYRON R. STOWELL - Representative of the - { G. T. Barnsley, E. Swensson, W. G. Wilkin .
Patterson Sargent Co., Cleveland, O.
1005 Park Bldg., Pittsburg. Pa.

CHAS. PARKER WAGONER, Eng. of Plate Dept., { H. M. Wilson, F. S. Rice, L. F. Hildner.
Riter-Conley Mfg. Co.
h , 238 Lehigh Ave., Pittsburg, Pa.

MR. CAMP—We now have something over 800 members and the Secretary will shortly send out a number of blanks to the members to be used to secure new members, and if you will all do your duty, we will have no trouble in reaching the mark set in our motto—"1,000 members in 1903." The Secretary will also short-

ly issue a new list of the members and we wish every effort made to have as many names as possible included.

A motion to have the Secretary cast the ballot admitting to membership those whose names have been read was passed.

MR. BARNESLEY—As Chairman of the Reception Committee I will report that we had a Smoker on the river Friday evening, September 25th, in which 43 members participated. The boat was contributed by Captain Kline.

Our excursion to Brilliant on the tenth of October, was quite a success. According to the program, we left Union Station at 1:30 P. M., with 97 members, the transportation being furnished by the Pennsylvania Railroad Company. Some others joined us at Brilliant, making a party of 105. While viewing the work being done on the Government dam No. 2, we were very nicely entertained by the Dravo Contracting Company; Assistant Engineer Brown and Engineer Reed, of the Columbia Construction Co. In this connection and also with reference to the rather unusual courtesy extended to us by Captain Kline in furnishing a boat free of charge for the Smoker, I would like to ask the Society to pass a resolution of thanks to these gentlemen, and if same is in order, would make a motion to that effect. Motion seconded.

MR. CAMP—The resolution, gentlemen, is to the effect that the Secretary be instructed to write letters to the gentlemen who have been named, thanking them heartily for their kindness and courtesy to us. Motion carried.

MR. CAMP—We have to-night a very interesting series of papers on a very interesting problem. It should, of course, be understood, however, that we are not attempting to discuss this matter in a fault-finding spirit with reference to existing conditions, but, taking much broader ground, we shall try to arrive at some definite conclusions regarding the engineering side of the transportation problem which confronts us. I will first call upon Mr. Swensson to present his paper entitled "Notes on Rapid Transit, With Special Reference to Pittsburg."

NOTES ON RAPID TRANSIT WITH SPECIAL REFERENCE TO PITTSBURG.

BY EMIL SWENSSON.

1. The law of evolution governs the development of the facilities and methods employed in the transporation of passengers within cities. The first cost and prospective return on the investment are the most important controlling factors in the selection of method of construction, of routes, of the system of operation and the mileage of road. The rotation of such evolution up to date has been as follows:

Omnibuses or hacks, horse cars, cable cars and electric cars, moving on the surface of the streets; the elevated structure for cars, moving above the street level, and the subway for cars, moving below the street level.

2. As the different methods vary greatly in first cost and also in cost of operation, the feasibility of any particular transit project must necessarily be governed by the possible earnings of same, which must be sufficient to pay interest on capital invested.

3. Thus we must include the above features in the consideration of the engineering side, when discussing any traction problem.

4. Therefore, any projected transit system, whether ordinary or rapid, must be a bankable scheme; that is, prospective revenues must be sufficient to pay interest on cost of system, or capital will not be forthcoming for its consummation.

5. A practical system should serve the most populous section and connect the objective points by the shortest direct route, giving quick service. By so doing, it will serve the majority and receive the largest obtainable returns.

6. Its patrons must be well distributed or collected in the down-town section of the city, by means of loops, and thus accomplish the primary object of a transit system, namely, that of relieving the street travel and possible congestion at certain points in said section.

7. However, a system cannot be expected to carry each individual direct from his door-step to his office door, neither can it be expected that a system will only pass in front of the

other fellow's residence, and still be of service to the majority of people in the community.

8. The main objective point for city travel being the down-town or center portion, where all the radiating lines must concentrate, the efficiency of a rapid transit system must be measured by its down-town facilities for distributing and collecting the passengers, especially at the evening rush, when our business life demands that everybody must reach their respective homes within the same hour.

9. A system that would have its terminus on the edge of the down-town or business section, can neither be popular or satisfactory to the majority, and consequently, not remunerative to the investors.

10. Human nature must be taken into account carefully in planning a rapid transit system, as the individual is very particular about his comfort and convenience on his regular daily trips. As a rule, the individual knows only the most convenient route and mode of transit between his place of daily toil and his residence, and cares very little whether or not this route is convenient to the majority of his fellow citizens. A transfer, a railroad grade crossing will make a route less patronized than one not having these inconveniences.

11. In the spring and fall great fluctuations in the number of passengers carried on the several routes of a street car system is noticed, as closed or open cars are not interchanged with every change of the weather. This is especially the case when steam railroads happen to be running in the same direction with the street car routes, the traffic on the railroad increasing materially in the fall and decreasing in the spring. (Sight Boston case here.)

12. As a rule, a proposed new route or system to which the individuals raise the most objections is usually the most practical, and will always serve the most people in the community. The line to which no objections are raised will serve nobody and reach nobody.

13. The selection of any particular method of construction and operation of a rapid transit system must be governed, not only by its first cost and prospective revenues, but technically by the topography of the city as a whole, by the relative elevations of

the down-town or business section and its residence section; by the width of the streets, etc., in the down-town section; by the value of available private property in said section; by the sewerage system, etc., of said section; by the relative elevation of water, and its variation, in the adjoining water courses to that of the city streets.

14. Whatever system has been selected for the down-town section of the city, as being most feasible and profitable, will usually govern the rest of the system in the out-lying district. It is not good engineering to select the system in the out-lying district first and expect the down-town section to be taken care of somehow or other. The down-town section has the most traffic, of all kinds, and should be primarly considered.

15. Whatever system adopted, it should be laid out for the future growth of the city it serves, and so laid out that it can be built piece-meal and extended as the demand for it grows. Every section of it which is built should give the best service for the time being.

16. If a subway is under consideration, it should be borne in mind that there is a vast difference between merely tunnelling under a water course and building the main terminus of a system below water level.

17. Comparing the relative merits of an elevated structure and a subway, it is noted that an elevated structure is unsightly to the eye and disfigures a city, but it is certainly more pleasant to travel on than in a subway. An elevated is noisy to the people dwelling along its line, not more so, however, when operated electrically on the multiple system, than surface lines running as many cars; but a subway is by far the noisiest to the passengers traveling in same. The subway is unhealthy, with its chill, damp air, ladened with poisonous gases, especially in the summer time, when the outside air is warm and dry; when on the other hand, an elevated is not only healthy in itself, but by its moving cars, produces purifying air currents throughout the street. Experience has shown that an elevated is less dangerous to life and limb than a subway; a subway is subject to bursting of sewers, and water and gas mains, etc., and when running below the water level, is subject to flooding from adjoining water courses.

A subway is more dangerous than an elevated in case of the electrically operated cars catching fire by confining the smoke and passengers.

18. Although an elevated apparently obstructs the street through which it passes, it is mostly in the air—and light—space above the street, only the columns and landings of stairways obstructing the street surface itself. A subway, in narrow streets, practically occupies the entire space under street surface, which place is now occupied by the sewerage, water, etc., systems, and at stations, several hundred feet for each, it must encroach under the sidewalk, and also under the buildings adjoining. In fact, in the down-town section of most cities it will be necessary to have the entrances to subways on private property, and just at points where it is most valuable. Where the entrances must be located on the sidewalk, they take up more room than stairways to an elevated.

19. This question of stations is by far more serious on a subway than on an elevated; in this respect Boston had some very difficult problems to take care of.

20. The cost of construction of a subway is from two to three times as great as the cost of an elevated, and the cost of a subway in the narrow down-town streets with a complex underground work of sewers, pipes of all kinds, high buildings, many of them with poor foundations, heavy street traffic, and the necessity of procuring costly private right-of-way for stations, makes it very excessive over what the cost of an elevated in the same section would be.

21. Referring particularly to the rapid transit problem for Pittsburg, we must first fix in our minds that congestion of people on the cars is a different thing from congestion of cars on the streets. The congestion on the cars does not affect the engineering side of the solution of the problem, it being simply a question of more cars, so we can exclude this; but the question of congestion of cars on the streets of the down-down section is the vital one, especially so, as the vehicle and foot traffic on the narrow down-town streets is now so great, as almost to demand the streets all to themselves, exclusive of any street cars whatsoever. Thus the cars must be either run overhead or under-

ground, on loop or loops, which should cover this section thoroughly and be accessible to all the radiating lines of passenger travel.

22. When facilities for taking the cars off the streets in the business section is provided for, and more cars can be satisfactorily handled in that section, the main point of the problem has been solved, as the additional cars can, for the present, be taken care of on the surface of the streets in the residence section of the city, where there is no congested traffic on the streets.

23. At the present rate of growth of population of Pittsburg, it will soon be necessary to extend the down-town structure, which ever is selected, to the residence section. It is, therefore, imperative to consider the probable extensions before finally selecting the down-town method of relief. Taking into consideration alone the steep grades necessary on our streets, connecting the lowlands with the hills of the city, the overhead method is most practical for the down-town section, as it permits of reducing somewhat the said grades.

24. Our grades are so steep and long that only the electric power, used under the multiple—unit system (perfected only a few years ago), has made it possible to operate satisfactorily and economically a rapid transit system of trains on a structure, parallel to these grades, whether overhead or underground.

25. In the down-town section of Pittsburg, the elevated type of construction is far more feasible and practicable than would be a subway. In fact, a subway is nearly prohibited there, as it would be below flood stage of the river, which frequently submerges some of the streets; as it would materially increase the already high rate of grade to the hill districts; as the streets are so narrow that the sewers would have to be rebuilt under the subway or under the sidewalks, which are now mostly occupied by the abutting properties, in either case requiring the collecting of the sewage in pools or sumps, and then pumping same at several points on the route, and to put the subway under the sewers is out of the question, as it would be too deep to reach with stairways, be below the foundations of the buildings, and be more difficult of extension to the hill district; as some of the entrances to stations must be raised above the street grade, to keep above

floods, and several of the stations must be located on private, and very costly property, as the streets are too narrow to take care of them; as it would be the terminal of the system, always crowded with people, its flooding would amount to a catastrophe; and lastly, its very great cost, compared with an overhead construction.

26. Thus an elevated road is undoubtedly the best solution for the relief of the down-town section, and being the key to the situation in Pittsburg, what is most practical there would and should also be satisfactory for the balance of the city.

27. Such a road should be in the shape of a loop, with spurs running out in the lowlands of Greater Pittsburg and then to and into the hill-sides at the various points, where the present surface lines could be taken out on such elevated loop, and again delivered to the surface at the same point, on its return.

28. The spurs on the lowlands can be extended over the bridges without interfering with the traffic on same, and continued over the busy main routes of traffic to the hills, extending either through the hills, on the surface or overhead, as conditions may dictate.

29. Referring to Pittsburg proper, one elevated spur could go out Liberty Street to 34th St., and for the present, ending there, connecting to the surface, receiving the Butler St., the Penn Ave. and Liberty St. lines. A spur could run out from the loop over Second Ave., over the Panhandle freight yard, and reach the surface at Forbes an dShingiss Sts.; another spur could be run out from 7th Ave. to a point where it would take the hill cars off the surface, and it could also run to the Boulevard and continue as surface line on the Boulevard. Such arrangements of the loop would give the first and most urgently needed relief to the business section.

30. Any of these spurs may be extended as elevated when the traffic of the future shall so demand.

31. The most serviceable extension for the out-lying districts and one which will be first required, and perhaps it is already needed, as it would run through the center of the most populous district, is the extension of the Liberty St. route out Penn Ave., Frankstown Ave., Bennett St., Wood St. to loop in Wilkinsburg.

32. The 7th Ave. spur, besides its possible surface extension over the Grant Boulevard, can also be extended by a tunnel through the hill, coming out at Center Ave. and Neville St. Such a tunnel would, however, be rather excessively costly for the results it would produce, as it does not reach a district of sufficient population to make it a paying investment, in itself.

33. The spurs at Second Ave. and over the Panhandle freight yard can be extended out Forbes St., or Fifth Ave. and Forbes St., as an elevated and cut across the town on the line of Neville St., making a large loop, connecting with the Penn Ave. line, assumming that the Penn Ave. line will be first built. This extension may take another course out Second Ave. to Glenwood as an elevated, and thus give special service to the Monongahela valley. From same, a cross town route, on the line of the Pittsburg Junction R. R., would form a loop connecting the two river valleys.

34. Looking at the situation as a whole, Pittsburg has not yet reached the subway stage, and conditions seem to demand first and mainly an elevated system, but if a tunnel to the East End section should be preferred, the shortest and best route is from 7th Ave. and Webster St., there connecting to the down-town elevated loop, running out on the line of Wylie Ave. to Center Ave. and Neville St. Any other tunnel route through the central hill district is longer, the longest being the one running under Locust and Aliquippa Sts. to Center Ave. and Neville St., the latter being fully one mile longer than the former.

35. But whatever route of the tunnel, a down-town elevated loop is absolutely necessary to distribute and collect the passengers, to make the scheme bankable, as there is no room for any more surface cars there. A tunnel route only a couple of miles in length and on which high speed could be used, would not induce sufficient number of passengers to walk to the station of the tunnel, located on the edge of the business section, to make it a paying enterprise. That such would be the case, can best be judged from the fate of the "Grant and Shady" car line, (which had to be discontinued for want of patronage).

36. The extension of the transit system from above mentioned eastern mouth of the tunnel is also a matter for careful

consideration. If the extension is made on the surface, the rapid transit or time feature becomes minimized; if in a subway, the cost would largely increase, and not being so flexible as an elevated, it will not so readily and fully reach the most populous, or "nickel" sections, as will the Liberty-Penn Ave. elevated line, extended through to Wilkinsburg.

37. Any tunnel route through the central hill district, can at most, only serve the down-town section, and does not reach the Allegheny River lowlands above 11th St., which are now of much importance, and are fast becoming more so, as the best location for the smaller manufacturing establishments; should the present growth, in this direction, of said district continue, it will soon be as important a district for passenger travel, as the down-town section itself; the great number of people working there require rapid transit facilities, which would be given by the Liberty St. and Penn Ave. elevated, at the same time it so admirably serves the down-town section, by running down Liberty St., which is practically the center of the two cities.

38. Granting that the Liberty-Penn Ave. elevated route is the one most needed, and in every way most feasible, but also admitting that the Shadyside and Bellefield districts require immediate rapid transit facilities, same can be best accomplished, at once the elevated loop is built, by the above mentioned Grant Boulevard surface route, running out on the elevated loop down town. This can be accomplished without materially affecting the vehicle travel on said boulevard, by laying the tracks close to the hillside and separating same from the roadway by a fence. And if the width of the roadway must be preserved, it can be extended out to the edge of the retaining wall, the sidewalk on said side being carried out on overhanging brackets on outside of said retaining wall.

39. It will be noticed that from the above discussion of the needs of the City of Pittsburg, the ideas here suggested, being flexible, admit of extensions from time to time, as the growth of the city demands, beginning with the elevated loop down town.

MR. CAMP—The discussion of these papers will be deferred until all papers have been read.

The next in order is a paper on "The Effect of Multiple Control on the Traction Problem," by Mr. N. W. Storer.

THE EFFECT OF MULTIPLE CONTROL ON THE TRACTION PROBLEM OF PITTSBURG.

BY N. W. STORER.

The traction problem in Pittsburg is essentially the same as in many other large and growing cities. The largest part of the business of the city is transacted in a very small area of the down-town section. The standard business hours require that people should go to work between six and nine A. M. and stop work between four and six P. M. This makes it necessary for the traction company to transport the largest part of the laboring and business classes to their work between six and nine A. M. and to their homes again between four and six P. M. The results of this concentration of travel in these hours, are very much overcrowded cars, and a very high peak in the load curve of the traction company which is extremely difficult to take care of. The problem is, how to move these people at the time they wish to be moved, quickly and without the overcrowding, which is so detrimental to the health and comfort, patience and future salvation of the passengers. It is a difficult problem, partly due to the topographical features of the city, and judging by the results, one that the Pittsburg Railways Company has not yet solved. The results are so annoying that many of the residents of our city even have an idea that the problem, as viewed by the traction company, is more one of finance than of engineering—a problem of nickels rather than the comfort of their patrons.

The question of expense and profits is certainly one that is very properly kept in mind, but it can hardly be said to occupy the entire thought of the traction company, which is constantly improving and enlarging its service in many ways. There is no question but that the service is much better than it was before the consolidation, but the city has increased and grown so rapidly at the same time, that the improvements are largely lost sight of.

But, whatever may be the idea of the Pittsburg Railways Company as to the traction problem, the engineering side of the question is, how to move the people.

It is manifest that the problem involves, first, last and all the time, the passage of a sufficient number of cars through the crowded parts of the city at all hours of the day and night to accommodate the people who wish to use them. The difficulties in the way of this desideratum may be enumerated as follows: (1) Lack of cars. The company may not have enough cars, or if it has the cars, may keep them in the barn instead of on the road. (2) Lack of power. If the supply of power is limited, it may reduce both the number of cars and the schedule speed. (3) Lack of routes. There may be an insufficient number of routes through the city. (4) Lack of speed, caused by overcrowded streets or inefficient handling of cars.

The first two limits are questions for the management of the company to remedy—it is simply necessary to supply as many cars as can be used and to provide for them an adequate supply of power. It is certain that both of these limits are particularly active in keeping down the number of cars at the present time. Observation of the traffic in the down-town streets at the crowded hours will convince any one that the number of cars is not as great as it can easily be. One may frequently look for a block or two during rush hours without seeing a car, and this when there is no particular reason for it except simply a lack of cars. That there is also a scarcity of power, we know from frequent statements in the newspapers that are evidently inspired by the company.

The third limit, that of routes for new car lines, is discussed at length in the other papers, but the chief reason for urging new routes is not to much to secure greater capacity, for the present routes properly operated will have ample capacity to carry all the people, as to furnish, by means of elevated railway or subway, a more rapid transit from the center of the city to the suburbs.

The fourth limit, lack of speed caused by overcrowded streets or inefficient handling of cars, is the one to be considered in this paper, with the object of showing one way to improve the present maxium number of cars over the existing routes, or how to improve the service with the existing track facilities.

Although in Pittsburg the present lines may not now be worked up to their full capacity, the present system of operating

single cars in crowded streets is in itself inefficient and productive of delays.

(1) Because there must be between any car and the next a space, the amount of which depends on the speed at which the cars are operating, or the distance the car will move after the signal is given before it can come to a stop. Cars moving at the rate of 10 m. p. h. will move a distance of 40 to 50 feet after the signal to stop is given, even with very quick braking. This space not only decreases the possible number of cars on the street at one time, but it decreases the schedule because of the greater number of chances for vehicles to slip in between the cars.

(2) Because of the great number of independent units which necessitates the cars stopping and starting successively on the crowded street. This is especially inefficient at crossings where one unit at a time must cross and delays are very frequent and annoying.

The use of trailers should help this to some extent, but the good effect of operating two cars together is more than neutralized by the greater difficulty of controlling the two cars, the slower acceleration, slower running and slower braking, which reduce the schedule speed for all the cars.

The scheme which is proposed as a remedy for this difficulty is the multiple control system, which is a development of the last four or five years. Briefly, this system is one which permits the use of two or more fully equipped cars as a single unit controlled by one motorman. Its use at present is confined almost exclusively to elevated railways and subways in the larger cities, and to interurban electric railways, but it is only a question of time when it will be used to a great extent on the surface lines as well. Its merits are undeniable and when the street railway officials once become acquainted with its advantages, nothing but the cost of changing will deter them from adopting it at once.

With this system each car has its full complement of motors as at present, but the control system is different; instead of having a large controller in the motorman's cab, there is only a small "master-switch," looking like a minature controller. The main controller which carries the current passing through the motors is usually placed under the car. It is operated by either

compressed air or by electro-magnets or solenoids. In the controller manufactured by the Westinghouse Air Brake Company, for the Electro-Pneumatic System, the motive power is compressed air from the same reservoir that supplies the brakes, the valves being actuated by a small current which is controlled by the motorman's master-switch. The connection between the cars is made by a train line cable, containing seven small wires which are connected to the master-switch and by means of a plug and socket connection to a similar cable in the car at either end. By means of this train line the motorman is able to operate the controllers of all the cars in the train simultaneously. This, in connection with the air brake, gives the motorman the most perfect control of the train.

The electro-pneumatic control apparatus is made up of standard pieces of apparatus which have really been in use for a long time. The small magnets controlling the valves for the air cylinders are the standard magnets which have been successfully used by the Union Switch & Signal Company for many years. Operating with only fourteen (14) volts on the train line, there is practically no possibility for them to give anything but perfect satisfaction. The pneumatic parts of the controller are simply modifications of the standard air brake apparatus. The main controller used for the large motors on elevated service is composed of thirteen individual contact devices which are designed in a manner dictated by long experience. For the smaller motors the main controller may be of the same general type, but much smaller and cheaper.

Some of the special features of this system introduced in connection with the master-switch are worthy of mention: First, a perfectly uniform and automatic acceleration is assured. The rate of acceleration is decided upon and the controller is adjusted for this before the car leaves the barn; then all the motorman has to do is to throw on his master-switch and hold it while the automatic feature does the rest. At the same time, it is within the power of the motorman to notch up the car faster, if necessary. As this will be more trouble to him, however, he will follow the path of least resistance and use the automatic acceleration. This should appeal to everyone who rides on the Pittsburg

street cars, where the acceleration and braking are beyond description. It should appeal to the company because of the great saving in power that would be effected by the proper handling of the controller.

A second important advantage is in the fact that the master-switch is so constructed that if the motorman should, for an instant, lift his hand from the handle when the current is on, the power will be cut off, the air brakes automatically applied, and the car will come to a stop. This feature gives it the name of the "dead man's" handle, for the passengers would be perfectly safe if the motorman should drop dead at his post; thus, the interests of both passengers and company are safeguarded.

In addition to these positive advantages, there is the added advantage for the multiple control in the fact that the motorman does not have to exert any great physical force. The master-switch and the engineer's valve for the air brake require practically no exertion and the motorman can consequently devote his entire time to the proper handling of the car. By the use of these appliances it is just as easy for him to handle a train of a half dozen cars as a single car, and very much easier than it is to handle a single car with the present cumbersome controller and either hand brake or power brake.

The multiple control system would have the advantage of the present system in removing the defects which have been pointed out in the present system: (1) It allows more cars on the street at one time by decreasing the total idle space between them. (2) It removes a blockade much more quickly by controlling several cars as a unit than is possible with a single car system. (3) It reduces the delays at crossings very nearly inversely as the number of cars operating together. (4) It affords greater facilities in loading and unloading passengers, as both front and rear platforms can be used on the rear cars. The loading and unloading will also be greatly simplified by having more cars so that the crowding will not be so great. (5) It permits of just as rapid acceleration, high speed and quick braking as if the cars were operating singly, may even give greater accelerating power, because there will be less liability for slipping of wheels, for if the wheels of one car should start to slip, the others would push it

along over the slippery track until the wheels could once more take hold of the rail.

The objection may be raised that the traffic on any route of the city will not warrant the operating of two or three cars together without increasing the time between cars. This is hardly true for any of the routes in the city at the present time during the rush hours; but, if it should be the case that with the maximum number of cars operating over the down-town tracks in trains of two or three cars the distances between the cars on any given route were excessive, it can easily be remedied by coupling cars together as they reach the same track or the crowded parts of the city, and running them with a single motorman through town and back until they come to the parting of the ways once more, when they could be separated and run independently. This is easily possible and would probably result in a considerable reduction in the number of motormen, since the Fifth and Highland cars, for instance, could be attached to the Wilkinsburg cars going out Fifth Avenue and could branch off when they come to Highland Avenue. The motorman operating on Highland Avenue could simply run the cars back and forth there and his time for the down-town trip from Highland Avenue would be saved. It is an extremely simple matter to couple the cars together for this system, and, in fact, the Westinghouse Air Brake Company has designed an automatic coupler for heavy trains which will couple the cars, the air hose and the train line with one operation. Such a coupler could, no doubt, be designed for street cars, so that it is a very different matter from picking up a trailer.

The objection may be raised that this system involves the use of more apparatus on the car. This is true, but the apparatus is simple and with the low voltage on the train line, as stated above, there will be practically no liability for any trouble; but even if it does require more care in inspecting the car, it is no more than the company should be willing to give to a system which will, in the end, make far more more money for them and give vastly greater satisfaction to the public. The multiple control system will undoubtedly make it possible to operate 50 per cent. more cars than is now possible with the single car system

through the crowded parts of the city; this, together with the possible increase in the number of cars by other simple modifications of the present system, would render travelling in the street cars a pleasure rather than a burden to the people of Greater Pittsburg.

MR. CAMP—The hard-working Chairman of our Program Committee will now give us his report made up from the blank forms sent out to members of the Society.

REPORT ON CIRCULAR LETTERS.

BY S. M. KINTNER.

In selecting the topic of discussion for this evening, the Program Committee had in mind an *engineering* topic that was *live,* and of local interest. There can be no doubt of the traction problem being a live one and of local interest. But to confine it to the engineering side only, is where difficulty is met.

It was not the intention, when selecting this subject, to plan an attack on the managements of any existing corporations, but rather to deal with it as an engineering problem, pure and simple. As we knew of no one that had been more closely in touch with the practical details of such an undertaking than the officials of the Pittsburg Railways Company, they were invited to present a paper telling of some of the many interesting engineering points involved. As their letters of acceptance have not been received, they have not been placed on the program of the evening. However, if any of the gentlemen are present, we shall be most pleased to hear from them.

The circular letters sent to you—and which a great many of you still have—were for two purposes:

First: To call your attention to the subject and set you to thinking on it, along definite lines, and consequently arouse a greater interest.

Second: To gather a certain amount of data as to conditions of service at the present time, and collect a number of proposals for improvements for discussion here this evening.

The first reason is perhaps of the more importance, and how

well the circulars answered their purpose, will be shown in the general discussion following the reading of the papers.

The second purpose, that of collecting data, it is my pleasure to show the results, in what follows.

While the number of replies received, to the circular letters sent out, has been rather disappointing, the quality of those sent in has been very gratifying. The character, reputation and engineering standing of the members responding being the very highest in the Society. The following classification will give some idea of the qualifications of the responding members to pass judgment on such a question:

Manufacturers	5
Vice Presidents, Large Manufacturing Co.'s	2
General Superintendents	2
Civil Engineers	12
Mechanical Engineers	14
Electrical Engineers	10
Contractors	8
Shop Superintendents	4
Sales Managers	6
Draftsmen	4
Miscellaneous	7
Total	74

The replies show that all the thirty different lines, represented in the answers, are crowded uncomfortably during, at least, two periods of the day, and a number report four periods of uncomfortable crowding. These times of excessive travel are about the same on all the lines, starting at about 6:30 and extending to 9 A. M., and in the afternoon from 4:30-6:30. Again, on some lines there are two periods in the evening when the crowding is excessive: 7-8:15 and 10-11:30 P. M. The time between cars on the several lines varies all the way from 3 to 25 minutes, with an average for all lines of about 8 minutes.

The question of other available lines brought out the almost unanimous opinion that the steam suburban roads were seldom, or never, crowded, while all traction cars on all lines to the same district were always crowded at the rush hours. No new surface

routes were discovered between the congested district and the East End, excepting the proposal to use the Grant Boulevard.

For Allegheny, the district of the Western Ave. and Woods Run cars could be given relief by the operation of a car line over the Union bridge. Such a line is built, but is not operated aside from a car every hour or so.

A Sharpsburg proposal is for a line across 19th Street bridge and to the city. Several other routes were mentioned by other correspondents, but were for branch lines for very special localities and so are not of general interest.

The subway question met with favor. About 70 per cent. of the replies answering this in the affirmative. Several proposed a subway to about Ellsworth Ave., and then a distributing point for surface cars, or an exchange point on transfers, it being intended to run cars through to the city without stop from that central point, the subway to start in the down-town district at a sufficient elevation to protect against flood, and carrying the cars through the down-town district on elevated roads, if necessary.

The questions of elevated systems as a solution of the difficulty, while being answered in the affirmative in the majority of cases, was not looked upon with as much favor as the subway proposition. The principal objection to the elevated, judging from reasons given in certain of the replies, was the unsightliness of such a structure on the streets, and the effects on adjacent property.

The automobile service was looked upon as entirely unfit, by a very large majority—street congestion being the principal objection.

The moving sidewalk proposal as contained in question No. 7, met a sadder fate than the automobile service, as a regular, Noah's Ark minority favored giving it a trial even.

The next question was, unfortunately, quite generally misunderstood and was taken to mean the running of an express car service through from East End to Allegheny with very few stops, etc. The very natural objection arose to such a plan, that local and express cars could not operate on the same tracks safely. To obviate this difficulty the suggestion was made, to utilize Penn

Ave. for through service only, and Liberty and Forbes Streets for local traffic.

The point the question was intended to raise was the advisability of a car service through from East End to Allegheny, or from South Side to East End, but doing a local business all the way, the object being to take the car through the congested district in the business part of the city but once, in place of twice, as at present. Such an arrangement by properly choosing the routes, would enable a much greater number of cars to get through, as their loading and unloading distance would be cut in half. The opinions expressed in the circular letters, owing to the ambiguity of the question, cannot then be applied to either of the two possible interpretations.

The request for suggestions on methods of operating the present systems more effectively brought out a great number of schemes. The following are the ones that can be mentioned in polite society:

1. More cars.
2. More trailers.
3. More power to move present equipment.
4. Have system of loops not coming into the down-town district.
5. Varying down-town loops.
6. Extra fare cars for those objecting to crowding.
7. Provide four-cent fare at early hours to tempt bargain hunters home.
8. Cars stop at every fourth block only.
9. Provide better entrance to cars, i. e., side entrances in middle of cars.
10. Run cars in trains.
11. Use multiple control with cars in trains.
12. Build double-deck streets, using upper deck for passenger traffic and all travel, of a light nature requiring rapid transportation, all heavy hauling to be done below.
13. The use of a double-decked four-track system over the Pennsylvania tracks, two of these for local service and the others for through service, becoming local at the far end of the line, cars

leaving the elevated system at convenient points and operating as ordinary surface cars along regular routes.

14. Larger cars.

15. Cars on the various lines that are intended for local traffic only, not going the entire length of line but switching over on the return tracks before reaching the congested district, and thus giving the people along the central part of the route a chance for a seat. As, for example, have cars in Allegheny that do not come to Pittsburgh, but run from a point near the Market House on out to the ends of various lines.

16. A cheap cab service, similar to that in use all over Europe.

17. Walk.

MR. CAMP—The discussion of this subject certainly covers quite a broad field. With regard to the papers presented here this evening, I feel something like the German who went to a bank of doubtful standing and wanted his money if he could not get it, and didn't want it if he could get it, and so here to-night, we want everyone speaking to talk but a few minutes if a number want to speak but if only a few desire the floor, then we want each to talk at greater length. There has been much presented here for consideration and the way is now open for discussion of the many interesting points which have been raised. Mr. Wilkins, what have you to say in this connection?

MR. WILKINS—I think Mr. Swensson has the meat of the whole situation in his paper, and believe he is entitled to a vote of thanks for the clear way in which the proposed improvements in the traction situation have been outlined. It seems to me his ideas are pretty nearly right. He has given the matter much study and is familiar with all the local conditions and difficulties.

MR. WHITED—There is one thing which occurs to me in connection with the proposition to use Grant Boulevard for rapid transit purposes, and that is that such a movement might meet with legal difficulties. I am not sure about this but I am inclined to think it would.

MR. YARDLEY—It seems to me you cannot discuss this engineering problem intelligently until you take up the political

problem. All who have spoken here this evening have apparently inferred that these traction lines, etc., were to be built by private corporations. I think the first question is whether the City of Pittsburg is to build them or whether a private corporation is to build them. The movement for municipal ownership is a growing one over the country. We as public spirited citizens, might submit to a great many annoyances in regard to location of routes, etc., and there might be a great many things which would simply be unendurable if we were going to give them to a private company who would get the franchises whether they pay us for them or not.

MR. KNOWLES—The Society is to be congratulated in having presented such a comprehensive and instructive paper about a phase of our municipal existence needing the best and unbiased thought for its proper solution. The writer has certainly carefully considered and stated all phases of the question.

In many ways and for several reasons that portion of the Pittsburg traction problem, i. e., the getting of the people in and out of the down-town or congested portion of the city, can best be solved, as has already been so clearly set forth, by means of an elevated loop; but I am sorry to see some of my friends so inclined that no good can be seen in anything else. The particular problem to be met here first, seems to be one of transporting passengers quickly through the crowded down-town streets. Other parts of the city, because of the diversity of the routes, are somewhat more easily taken care of and the problem as to their needs can be solved as the occasion arises.

However, the use of an elevated loop down town does not prevent the adoption, for the purpose of avoiding difficulties on feeding lines, of whatever structure seems best adapted to the particular case to be solved. This statement is made with the belief that all forms of rapid transit should provide for running the same surface street cars as are now used, or may be adopted, continuously through or upon any new structure and back to surface again, and not provide for trains of special cars upon the elevated or through a subway as the case may be.

Subways, or tunnels, are used interchangeably with elevated structures without serious inconvenience to the comfort and

health of the passengers as is daily shown with the Boston system, where both elevated trains and surface cars use parallel tracks in the subway; and has been planned in the elaborte New York system, soon to be placed in operation, where tunnel, subway, or elevated structure, as the case may be, is used as appears best adapted considering the contour of the ground.

Whatever solution is best for the down-town portion will come first and the contributions or feeders to such loop system should be planned as seems best for the particular locality and deliver cars to this loop. Whenever means of rapid transit are needed between down town and East Liberty, or other semi-suburban territory, and I am not sure, referring to Mr. Liverson's remark about paying investments, but that such a route for express to traffic will not pay in the near future, such line or lines can just as well be tunnel or subway, as not, and deliver cars to an elevated loop system and receive them again to take to the outlying territory.

The objections to a subway, as expressed in the remarks about bursting sewers, bad air, noise, unpleasant traveling, etc., are all fanciful and should not be raised against modern construction and careful methods of ventilation and neatness.

Referring to a projected line through the hill, it is true that such a route can be much more direct and shorter to come out at Craig and Neville Streets, but this is not the only object desired. Another proposed route, viz., via Locust St., Soho, Allequippa and Center Ave., is somewhat more flexible in its arrangement assembling contributing lines and development has several advantages; one of receiving cars either from the surface or proposed elevated loop, at a point near where many routes now leave for the East End, Schenley Park district and up the Monongahela Valley and thus not causing serious rearrangement of present routes. Second, of having a distribution station at Soho for at least three separate routes; third, the possibility of using a terminus near Center and Craig at first, and later converting this into a station and continuing to the corner of Center, Ellsworth and Highland Avenues, where cars can come to the surface and distribute over the several surface routes now used to Highland Park, 21st Ward, Homewood and Wilkinsburg districts.

In regard to statements of costs, too many contingencies accompany each case to warrant deductions from costs at other places. In general, an elevated structure for the same service, costs less than a subway or tunnel, but damages to adjacent property in busy down-town streets may more than offset structural cheapness and cost of underground charges in building a subway.

Examples of the costs of various sections of the Boston Subway system show that the cost complete of the two-track routes varied from about $1,000,000 to $2,000,000 per mile and for four-track routes between $2,500,000 and $4,000,000. In an estimate made in 1892 for cost of about 12 miles of elevated two-track road in Boston, the figures were about $500,000 per mile for structures, plus about $600,000 per mile for damages and equipment. The probable cost of the recently built system of about seven miles has been about $1,860,000, per mile, including all damages and equipment, this figure being determined from the authorized amount of stock. Damages are not yet settled.

Referring to the paper of one of the previous speakers relating to operating trains upon the streets, I cannot help but believe that, if per chance this is coming, it is far away in the future, and it is doubtful if it will ever be practicable upon our crowded streets. So far as I have known, such use of trains has taken place either for long routes over elevated structures or in subways, or, if upon the surface, then where grade crossings are not many and closely spaced. The frequent stops upon our down-town streets will make such operation impossible for surface use. Why, a train of three cars of usual large size will extend nearly the whole length of some of our short blocks and the train would only move its length each time.

MR. ENGSTROM—I cannot just follow the reasoning of some of the previous speakers in regard to this problem. From the report read by Professor Kintner, it would seem that fully 70% of the answers favored the subway. Mr. Swensson, in comparing the possible solutions of this problem, that is, elevated lines and subways, enumerated several reasons why the subway would not be the best method and the last reason he mentioned was the price. I think he made a mistake in that and that the matter of price should have been reason number one. Even if the subway could

be thought of in the down-town district the price would be absolutely prohibitive. Aside from the question of floods, there is another big objection in that when you go to build a subway you do not know what you are going to run across. At the Union Station, for instance, they wanted to lower a street and the contractors found out what was down below the street so far as they could, but when they got down there they found a sewer they knew nothing about. The Superintendent of the Bureau of Construction of the City of Pittsburg told me once an incident which illustrates what I mean. Some politicians in a certain neighborhood wanted a sewer on a street and came to him to ask him to prepare an ordinance. He asked them if there was any sewer there at all, and they said not. The records showed no sewer there and so an ordinance was passed and contract let to build the sewer. When they came to make the excavation, however, they found three or four sewers there which nobody knew anything about. So when you go to build a subway down town and run across obstacles like that, it is my opinion the cost would be prohibitive.

MR. SWENSSON—In my paper I made the statement that Pittsburg had not reached the subway stage yet. I still say so. There may come a day when we will be compelled to resort to subways, namely, when the traffic becomes so great that we will have no other choice and will be warranted in spending the money for them. I recall the time when New York City could only build elevated roads, because it had not yet reached the subway age in number of passengers to be carried. Now it seems to have reached that age. Then again, take Boston. I believe there are about 1,000,000 fares carried from and to the center of Boston every day, which, of course, was sufficient for a subway, when other conditions were favorable for same; but then conditions called for elevated roads for the principal extensions to that subway. Pittsburg has as yet not enough traffic to pay for cost of subways; and until it has, there is no use talking subways.

MR. FLANAGAN—This is a very interesting subject, and as Mr. Swensson says, the subways are a long way off, and it is possible that the elevated is a long way off also. It seems to me, therefore, that the plan outlined by Mr. Storer might be avail-

able. I think Mr. Storer might throw some additional light on that scheme and also state the length of time it would take the existing company to change to the plan he details. I know I go down to the corner of Penn Avenue and Sixth Street, and half the time up to Seventh or Eighth Streets, to get on a car. It occurs to me that, under the multiple control system of operating, three cars could be connected together and then make only one-third of the stops. That is to say, in place of stopping at every square, stop only at every third square. The present condition of traffic during the rush hours of the day would frequently load those three cars at one stop. When a man could get on at certain points where he would stand a fighting chance of getting a seat, he would wait there to get it. As it is now, if a man, by any possible accident, secures a seat then he feels ill-mannered all the way out—four miles out home—because girls and women stand up in front of him.

MR. LYONS—One suggestion has been made as to side openings in cars. There is no question but that this would afford some temporary relief because when you get up to 110 and 120 cash fares on one of those long cars it takes time to load and unload, and no matter which end of the car you start for when getting off, especially when the car is badly crowded, you are going to lose time. I noticed the other day that the Illinois Central is trying a new car in their suburban service, that is, one having seats arranged around like those you see in passenger stations, in the center of the car, and on either side, the doors are in the middle. All doors are arranged to open at once so that the whole car can be loaded and unloaded with ease and despatch. It is undoubtedly going to reduce the time limit in making stops at stations. Any one interested in this particular feature could undoubtedly get some good results by following up the service these cars render.

I have often watched local cars at some of the transfer points and noted how they handle the traffic where there is no dispatcher. When the car comes up to transfer points, they will often avoid getting their load, and in making their last trip, or at the end of their run, they will try to miss as many passengers as possible. I have seen this frequently.

There is another feature of this problem and that is that as long as it remains unsolved, we cannot expect the City to grow as it should. From all the information I can gather, the country back of Mount Washington is really finer than the East End and the only thing that is holding that back is the development of rapid transit facilities. Of course this is something for the very distant future, but so far as the financial end of it is concerned, there is a large amount of real estate behind those hills which must be developed and it would seem that only the transit facilities are necessary to do this.

MR. SWENSSON—In regard to the side doors, that is only practicable where you stop the cars at certain fixed stations, say a quarter of a mile or more apart. Where you stop at every street corner, it is not practicable. In other words what is good for the Illinois Central will not do for ordinary street car operation. As regards reaching the country back of our hills, as for example Mount Washington, my paper suggested many elevated spurs over the bridges to the lowlands of the South Side and Allegheny, and up over or under the hills. A tunnel is now being built for Mt. Washington opposite Smithfield Street bridge.

MR. ABRY—As Mr. Swensson has stated in his paper, the methods of transportation have been a matter of evolution for many years past, and the reasons for this condition are manifest to any one who will study the constantly changing conditions. The question of the use of multiple control on the streets in the congested portions of a city, I think is a debateable one. It might perhaps be done satisfactorily under certain conditions of headway, schedules, etc, and might not. However, the use of multiple control is certainly demanding attention in the railway field and whether it can be advantageously applied in the congested portions of large cities remains to be seen, but it certainly can be applied in interurban and suburban work. There is a growing tendency among the trunk lines entering our large cities to use this multiple control system and change completely to electricity because the service can be more efficiently operated and the trains more often. If this tendency continues, can we not hope for a possible solution to a certain extent at least, of this traction problem, in the use of electricity and the multiple control system by

the Pennsylvania Railroad Company for all their suburban traffic between the city and the outlying districts. This is being contemplated in other places and it is possible to have it here in Pittsburg. If such a plan were adopted and these electrical operated trains run a little further down into the business section, over an elevated loop perhaps, I am sure the present congestion would be very much relieved.

MR. YARDLEY—I would like to ask Mr. Swensson what is the effect of placing elevated railroads on the streets? Does this not destroy the street? Take Penn Avenue and Liberty Street for instance. Just when there is a prospect of getting them improved and when we think we are going to get the railroad tracks off of Liberty Street, it seems to me it would be too bad to destroy it with an elevated structure.

MR. SWENSSON—The effect, as I have observed it, is not that the street is ruined for all purposes. If it is ruined for one purpose it may be made better for another purpose. As a residence street it is certainly ruined, but as a business street, it is made better, if the street is a narrow one, for wholesale and retail business, not requiring window displays; if the street is wide, it makes a very good display shopping street. Look at Sixth Avenue, New York City. I do not know of a better shopping street anywhere than that. Our Liberty Street, which is our widest street, would not be damaged by an elevated structure; would rather improve it, as a wholesale and non-display street. An elevated structure on same would not affect it the same as the railroad track now does. It would never be a satisfactory display retail street, as its width will fill it with teams and street car tracks, being the widest down-town street we have. As regards the remarks made by Mr. Abry, I most heartily agree that the suburban traffic on steam roads can be more successfully handled by the multiple control sytem using electric power, but that does not say that the multiple control system is better for trains of cars, running on surface lines in the business portion of the city itself, and as he says and as I emphasized in my paper, the method of system must reach the central part of the business center of the city, to be successful.

MR. STORER—There seems to be some little objection to the

multiple control system for regular street railway service. The plan I had in mind for Pittsburg does not involve running half a dozen cars in one train. It means, I should say, not more than four cars and probably a maximum of three in one train. Such a system would certainly very materially increase the number of cars which it would be possible to operate over a line and thereby very greatly assist in relieving the congestion in the crowded streets. It is only in the crowded parts of the city and during the rush hours that I would recommend running trains. Where single cars are running very close together, they not only interfere greatly with each other but the wagon traffic is much more likely to interfere with them. If there is a blockade and all cars can be started at once, it will save a great deal of time. If they can be started in trains of three cars each, they can be started in very nearly one-third the time that will be required if the cars are operated singly. The condition of the streets at the crossings generally amounts to a blockade and there will be much less delay where the cars cross in trains than where they cross one at a time. So far as stopping on the down-town streets is concerned, all cars have to stop at every corner any way, and generally a good many times between the corners.

The cars may be easily operated in trains whether they run to the same locality or not, but every car should be labeled in unmistakable terms. In Boston they have signs placed in a prominent position on every car operated so that it is entirely unnecessary for anyone to be deceived as to the destination of the car he is entering. I will admit that it does not look as nice on the car as the arrangement on the Pittsburg cars, but it certainly does give the people an idea of where the car is going, and if our cars could be marked in some similar manner, they could be loaded up more quickly and get away in one-third the time they do now.

The chances for accident where the cars are operated in trains with the multiple control system would also be much less than with the single cars. The confusion on the streets is in proportion to the number of units and where the cars are operated in trains there would be greater intervals between trains and thus this would allow for the crowds of pedestrains to cross the streets more easily and with much less interference.

So far as the elevated system is concerned, I think that will offer a solution for the down-town districts although when you come to the damage side of it, it may figure up nearly as much in cost as a subway. In Boston the property owners on streets where the elevated roads have run have been awarded damages of $5,000,000. That amount of money would put quite a hole in the ground. That does not mean, however, that I would favor the subway proposition in Pittsburg.

MR. SWENSSON—I think the question of damages has not yet been settled in Boston. Neither as regards damages nor cost of the road can Boston be taken as a guide, as its elevated is only a short line in the heart of the city and would be equivalent to our down-town loop only. Either the New York lines, or better still, the Chicago Metropolitan West Side Elevated would be better for companion with our conditions.

The questions of damages varies in different cities by conditions existing in each, and by the laws governing the matter in the different states. Speaking in general and judging from the experience of the existing elevated roads, the average damages paid per unit length of road is exceedingly small. It is true that some properties are badly damaged for certain uses, but it is equally true that other properties are vastly enhanced in value; take, for example, the Chicago West Side Metropolitan Elevated and the Union Loop of Chicago showing both conditions to one who studies their territory before and after building. Take a city as a whole before and after building of an elevated system and it will be found that the assessed valuation of property will be greater after the advent of the elevated road than before. Thus, if an elevated is assessed for damages to some adjoining properties, and other properties could be made to pay benefits, the balance would undoubtedly be in favor of the benefits.

Both in New York and Chicago we can find evidence that the large retail stores thrive best in the neighborhood of Elevated Stations, as would be the case in our Liberty Street and also some of the other streets, by changing routes of travel.

Where a necessity of the majority is under consideration we must not let our judgment be influenced by or based on the plea of the individual, who happens to be importunately situated as regards the march of progress.

MR. STORER—I understood that the first damage suits were clearly against the elevated people and that they were not going to fight it any farther and that the total damages amounted practically to $5,000,000. I have run over that Boston Elevated and so far as the noise is concerned, it is simply frightful. There are as many cars as on steam roads, there are more moving parts and in addition there are the shoes on the third rail which makes a continuous noise. The advantages in the electrical control is chiefly in the greater ease of handling trains and the quickend acceleration. The question of an elevated road in the down-town district of Pittsburg, I think, will best be solved by running a line as far eastward as Soho. Run the cars in trains down town, making very few stops and separate the trains into cars to go over their respective routes when they get to the end of the elevated. The transfer system should not be considered as it is not a good scheme. The transfer system in Boston makes endless confusion on account of getting from the subway to the elevated and vice versa. In regard to damages in Boston, I am creditably informed that they have not as yet been settled.

MR. SWENSSON—In regard to Mr. Storer's last remark, my paper contemplates at first no transfers whatever, but instead, the taking of the surface line cars off the streets and running them out on the elevated and putting them back on the surface again, by making connections to the surface lines on private property along the streets. It is only when the system becomes extended so far as Wilkinsburg, for instance, that it is contemplated to run regular trains on the elevated, and then we will have a regular elevated system which we can compare with those in other cities. So far as the noise in Boston is concerned, Mr. Storer selected the wrong example. The place to investigate in this direction is in New York City where the use of the multiple control system seems to have proved much more satisfactory than steam, decreasing the noise and increasing the comfort, cleanliness and cheerfullness of travel. There are good reasons for Boston being unsatisfactory as to noise. In the first place the elevated there is a lattice structure, which tends to rattle. In the second place, for certain aesthetic reasons, the sentiment of the Boston people demanded that the lower chord of girders should be curved, which make them a little shallow at the center, making a less stiff structure; but the worst of all is that they have the motors on one truck only, and larger diameter wheels on this motor truck than on the other

or trailer truck, which makes the cars heavier in one end than the other, and thus tends to give a hammer action to the cars, when in motion.

MR. HIRSCH—It is quite evident that Mr. Swensson has given a great deal of attention to this subject including the effect of elevated structures on narrow streets, and I would like to ask him for example, what the probable effect would be of elevated structures on our down town streets?

MR. SWENSSON— Some streets may be injured, some benefitted and some not affected, on account of which care in selection must be exercised. However, the fact remains we must have relief, and the elevated system is the only feasible down-town scheme.

MR. UHLENHAUPT—I think it has been well said that the matter of rapid transit is in a state of evolution in every city. It is the same in steam railroad practice. To-day we are riding in private cars where once we rode in the plainest kind of cars. We are constantly changing and improving to meet modern demands and necessities. In regard to the congestion in local passenger traffic, however, the transit facilities in New York City, at rush hours, are more than doubly as much crowded as are the cars on our streets to-day. There it is sometimes impossible to get even a position on the platform on the elevated railroad trains without waiting at least 15 or 20 minutes at some of the down-town stations. I believe that the corporations are entitled to a fair return on the money they invest, and just as soon as capital finds a fertile field for the investment of its savings you may be sure investment will take that direction and it would seem to-day that rapid transit work is about as good a field for it as possible. So far as the congestion is concerned, I do not know that anything will be lost by the crowded condition of the cars to-day. The trouble is that the existing power houses are over crowded and we have not as many cars as might be run, but that is going to be remedied just as soon as new and bigger power stations can be completed. I think the proposed routes laid out by Mr. Swensson will eventually be built, as soon as it seems evident that the project would pay, but on the whole, so far as Pittsburg is concerned, I think she need not give up hope yet. One point that adds to the conditions of congestion was that when the Consolidated Traction Company was building their lines, the manager of that company started out with the principle, which is fundamental in railroading, to allow any two cars running in opposite directions to pass each other. You will notice that the Consolidated cars have a very narrow aisle and when one person stands in that aisle it is obstructed. This, of course, was brought

about by the narrow streets, consequently at times when the rear half of the car is crowded to the platform, the front will be practically empty, simply because some one is standing in that car and will not allow the people in the rear to get up front. Another point is that if people would go on the car that would take them to the place they want to go and *not* take cars going twice as far as they want to go, a great deal of our present trouble would be over. Now in regard to the multiple control that Mr. Storer speaks about. Take, for instance, what I suppose is the most congested portion of the city so far as the cars are concerned, that is between Cecil Alley and Penn Avenue and Seventh Street. I do not believe the multiple control would solve that congestion for there are about as many cars passing along that street now as is possible. The general use of trailer cars might be of some benefit. In regard to the blanks Professor Kintner sent out, I might explain that I have mine in my pocket. I was unavoidably absent from the city and did not receive it until late.

MR. WORTHINGTON—In regard to this multiple control, suppose that in coming down some of these steep grades around Pittsburg, the machinery should break down so that the motorman could not control the train and the conductor at the rear would not be accustomed to look out for such accidents. Before they knew it they would be running away and they would have a bad wreck. It seems to me that is quite an objection to that system. It seems to me Mr. Swensson has covered all the points pretty well. I have wondered, however, how he is going to take care of Allegheny. He does not appear to have offered any solution for that district.

MR. SWENSSON—I was talking about Greater Pittsburg, and in that case the City of Allegheny does not exist. I think, however, you will find my paper covers your question in paragraphs Nos. 27 and 28, where it is suggested to run the elevated lines over the bridges and over the main routes of traffic in the lowlands, on either side of the two rivers, and either on the surfaces, above or under the hills, as called for by conditions in each case.

MR. CAMP—Any further discussion?

PROFESSOR KINTNER—Before a motion to adjourn is made, I would like to move a vote of thanks to the gentlemen who have presented us with very interesting and instructive papers this evening.

Motion carried.

Society adjourned at 10:15 P. M.

CHARLES W. RIDINGER,
Secretary.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and thirty-ninth regular monthly meeting of the Engineers' Society of Western Pennsylvania, was held in the lecture room of the Society's house, 410 Penn Ave., Pittsburg, Tuesday evening, Nov. 17, 1903, at 8:15 o'clock, Vice President J. M. Camp in the chair and 70 members and visitors present.

It was voted that the regular reading of the minutes of the previous meeting be dispensed with in view of the somewhat lengthy program for the evening.

The Board of Direction reported that it had passed favorably on the following applictions and present same to the Society for action.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
JAMES M. BARRETT,	Manager, Liberty Market Co. & Liberty Ice Co. h., 6214 Sellers St., Pittsburg, Pa.	D. Ashworth, V. Beutner, N. C. Wilson,
G. P. BARTHOLOMEW,	Chief Engineer, for The Rochester & Pitts. C. & I. Co. Punxsutawney, Pa.	W. B. Hough, C. W. Ridinger, H. D. Hershey.
WM. W. CONNER,	Salesman with Cahall, Sales Dept. h., 434 Atwood Street, Pittsburg, Pa.	N. C. Wilson, J. Hare, J. W. Landis.
CHAS. F. FRANSON,	Chief Engineer, James Stewart & Co., Westinghouse Bldg., Pittsburg, Pa.	F. Engstrom, P. Brynn, J. H. Tompson.
ERNEST C. HARPER,	Draftsman, with Riter-Conley Mfg. Co., 55 Water St., Pittsburg, Pa.	M. A. Gilbert, F. S. Rice, Z. H. Sikes.
JAMES W. HAYS,	Electrical Engr. & Contractor, Schmidt Bldg., 5th Ave., Pittsburg, Pa.	W. G. Wilkins, J. F. Kuntz, W. M. Judd.

SAMUEL R. JENKINS, - Resident Engineer, - { W. G. Wilkins, J. F. Kuntz, F. G. Ross.
on Construction Ambridge Plant,
American Bridge Co. h., Economy, Pa.

WM. W. KEEFER, - Asst. Gen'l. Supt., - { G.W.Schluederberg, E. J. Taylor, C. W. Ridinger.
Pittsburg Coal Co.,
232 Fifth Ave., Pittsburg. Pa.

RALPH E. MILLER, - Draftsman, - { M. A. Gilbert, F. S. Rice, Z. H. Sikes.
Riter-Conley Mfg. Co.
55 Water St.. Pittsburg, Pa.

EDWARD J. MOORE, - Mechanical Engineer, - { J. F. Kuntz, W. M. Judd, L. P. Blum.
with W. W. Lawrence & Co ,
Pittsburg, Pa.

CHAS. L. McKENZIE, - President, - { N. H. Finley, J. W. Walker, H. H. McClintic.
Pittsburg Construction Co.
General Contractors. 207 Bissell Block, Pittsburg, Pa.

WM. PIEZ, - Structural Engineer, - { W. M. Kratzer, A. D. Neeld, F. S. Rice.
G. L. Bollinger Co., Pittsburg, Pa.
h., The Narcissus, Bruston Ave. & Tioga St., Pittsburg, Pa.

ALEX. Z. NEWLIN, - Foreman, - { H. G. Wardale, L. C. Weldin, F. Z. Schellenberg.
Mechanical Engineers Office,
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DAETON PARNELY, - Clerk at Plant Furnace, - { W. E. Prindle, C. H. Rich, A. Curry.
Clairton Steel Co.,
Clairton, Pa.

C. D. SUPPLEE, - Asst. Engineer, - { W. E. Prindle, A. Curry, C. H. Rich.
St. Clair Terminal R. R. Clairton, Pa.
h., Elizabeth, Pa.

ANDREW J. TAYLOR, - Draftsman, - { J. McLean, F. S. Rice, Z. H. Sikes,
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ERNEST P. WHITTEN, Resident Engr. for East { S. A. Taylor, H. W. Gibson, C. W. Ridinger.
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Westinghouse Electric & Mfg. Co.
P. O. Box 911, Pittsburg, Pa.

J. WM. SMYTH, Salesman Insulated Wires for { S. Diescher, A. J. Diescher, L. C. Moore.
Electrical Purposes for Jno. A. Roeblings Sons Co., 109-111 Wood Street, Pittsburg, Pa.

R. G. SOMMERFELD, - Manager, - { K. F. Stahl, S. H. Stupakoff, H. W. Bernard.
Sommerfeld Machine & Mfg. Co.,
224 Third Ave., Pittsburg, Pa.

PER LEE ARTHUR YOUNG, Mechanical Engineer, { H. D. Lufkin, W. M. Judd, L. P. Blum.
W. E. & Mfg. Co., E. Pgh., Pa.
h., 724 Whitney Ave., Wilkinsburg, Pa.

It was voted that the Secretary cast the ballot for the election of these members.

MR. CAMP—If there is no further business we will proceed with the papers of the evening, and I will call on Dr. W. H. Ingram to read his paper entitled, "The Allegheny River, a Bacteriological Problem."

THE ALLEGHENY RIVER, A BACTERIOLOGICAL PROBLEM.

BY DR. W. H. INGRAM.

Of the many problems confronting municipal bodies at the present time, no other requires such careful consideration as that relating to the public health.

It is a recognized fact that the average inhabitant of both city and country district is woefully ignorant of the sources of the many diseases that are such potent factors, both to the individual and the community. They regard convenience and comfort more to be desired than the inconvenience and trouble required to protect health and even life. They put off the inevitable until forced by the occurrence of the inevitable. Strenuous efforts are made to abate the evil. It is passed over with, perhaps, an appalling death rate, and soon becomes a memory. Then a few, remembering the terrible consequences of the former neglect, try to keep alive its memory, stimulate anew efforts to remove its cause, and prevent its recurrence.

To many there exists a hazy idea that water is a source of some diseases, they know not how or what. They blame the water in the same manner that formerly they attributed disease to the wrath of the Almighty, and are willing to bow in submission.

These conceptions, from the fact, so well known, that the representatives and executives of most of our cities come from the non-technical, non-professional, and often from the most ignorant classes, are grafted into our municipal laws and ordinances. As a result, the efforts of these bodies, in procuring a pure water supply for the people, are often faulty, misdirected and even dangerous. That the gravity of the problem is partially recognized by them, is evidenced by the employment of commissions of experts to report the conditions existing. These reports

are seldom acted upon, unless stress be brought to bear by the better informed inhabitants. This stress being greater than they dare ignore, fearing either impeachment or loss of votes, and and greater than the inducements offered by corporations controling plants or devices in use, or to be used in procuring rapid and easy solution of the conditions. In short, the desire for "graft" is often greater than the desire to further the public health, and the reporting of the commission's findings is simply a "sop" thrown to the public to keep it quiet.

In speaking of this as a problem it presents itself to us under these conditions:

(1.) The nature and source of the danger.

(2.) The characters of the bodies having control of measures of belief.

(3.) The enlightenment of the people to the danger, its sources, and possibilities of correction.

In meeting with you to-night I feel highly honored to be included in so large a body of skilled men, who so clearly recognize the difficulties of this problem, and I feel it devolves on us, in part, to present a solution of the problem, by fearlessly doing all in our power to educate the masses to the gravity of the situation, and the possibilities of its solution. Education of the people is the surer way of educating our executive bodies.

With this in mind, I will endeavor to add my little to the solution, by presenting "The Allegheny River, as a Bacteriological Study." I use the Allegheny as being the least contaminated of the two rivers, and also as the principal source of our water, and ultimately to be the sole source.

That the water supply of large communities early presented difficulties, none will negative. Until bactereological investigations were made, all efforts were directed to obtain clear water. Then came the demonstration that the clearest, sparkling water could be the most dangerous water, for bacteria gave neither color nor taste. Not all bacteria in water were considered dangerous, but the relations of epidemics to sources of contamination, *i. e.*, from human habitations and disease, followed by strict scientific investigations, demonstrated beyond doubt that many diseases

are caused by impure water, or contaminated. Just how many and what diseases are so carried, is an open question. Without going into detail, it is recognized that the diseases receiving their infectious agents into the intestinal tract would be the most important. These include the various inflammatory conditions, dysenterias, typhoid fever, cholera, etc. Many are inclined to believe that tuberculous, diphtheria, smallpox, scarlet fever, and the so-called diseases of childhood, may be transmitted under certain conditions. The difficulties of experimental evidence in these preclude anything, at the present time, more than a deduction from analogy. From a study of epidemics it offers a suggestive field for investigation.

Of all these, the most important at the present time is typhoid fever. We can hardly realize that this is a preventable disease, when reliable estimates show that only three out of every ten people escape it, and that in Pittsburg the mean rate (per annum), from 1887 to 1898, was 81.6 per 100,000 inhabitants. From 150 to 300 people, in this city, may be found suffering with this disease at any given time. Comparing this with other cities, it is excessive, as may be shown by New York, with 21, and Boston, 31.9 per 100,00 people. Pittsburg shows one of the highest death dates of the cities of the United States.

That this disease, then, is alone of sufficient importance to warrant the most radical steps, is evident when we consider two factors: 1st. The disease is caused by a specific bacteria. The B. typhonis, or B. of Eberth; 2d. There are seven possible modes of infection, or ways in which this organism can reach the human body.

I need hardly refer to the fact that typhoid fever does not arise spontaneously, but comes from an antecedent case, *i. e.*, the bacteria are derived from the discharges of the patient, and by one of these seven ways enters the body of another individual. These secretions being feces, urine, blood, and probably sputum and sweat.

These seven sources of infections are: 1st, Atmospheric dust; 2nd, Uncooked or raw vegetables (turnips, celery, lettuce, etc.); 3rd, Uncooked or raw shell fish (oysters, clams); 4th, Ice supply;

5th, Milk supply; 6th, Secondary infection or contagion: 7th, Water supply.

Considering these rapidly, the first could be possible, but a rare factor, found only where such unsanitary conditions exist, as to allow fecal matter to partially dry in the air, and be carried by high winds, and thus inhaled or swallowed. The second is possible when human excreta are used as open field fertilizer, these excreta coming from typhoid patients. The third is produced by using shell fish from beds at the mouth of sewage contaminated rivers. The fourth is not as great as in former years, for in large, and even small communities, artifical ice, made from distilled water, is in common use. Pond or river ice is dangerous ice, for the B. typh. can remain alive at this temperature. The fifth is an extremely dangerous source, particularly where milk cans are washed in contaminated water, or the milk is diluted with the same type. There is no better artificial medium for this organism than milk, and epidemics of no small size have been traced to it.

That typhoid fever can be regarded as contagious, I am not ready to admit, the evidence so far not being of a clear enough character to warrent a conclusion. If a nurse or attendant should ingest any of the secretions of the patient, it is probable, but an unusual condition.

Rapidly reviewing these it is easily seen that the short periods of duration or application of these six factors, as compared with the even distribution of the disease regarding extent of territory and time involved, would not convince one that they were the principal causes. No doubt they are, to a small extent, contributing causes.

Finding that these six causes do not supply the contagion, it remains to consider the last, the public water supply, as the principal and important source of the distribution of the B. of typhoid fever; and thus, indirectly the cause of the excessive prevelance of this disease in Pittsburg.

Another factor is found in the method of supplying the water. It is pumped at all seasons directly from the river to the reservoirs, and, without filtration or any purification, distributed

to the people. The people then receive practically "raw" river water. This alone, from the hygienic standpoint, is dangerous. This must, however, be shown by direct and immediate proof to be an actual state of affairs, and be substantiated by evidence of sufficient value to warrant the enormous cost to the people of means of protection.

It then follows that in making an analysis of the evidence of this condition, we study, in detail, the following aspects of the Allegheny River water: 1st, The "watershed" drained by the river; 2d, The character of the river, so far as possibilities of self-purification of its water are concerned; 3d, The actual sewage and bacterial contaminations of the water, depending on these two; 4th, The remedies possible for the above conditions.

Examining the first of these, we find that the Allegheny River valley, like all the valleys in this part of the United States, presents a large watershed. Starting at the intake of the Brilliant pumping station, it is about 320 miles long, with an area of 11,400 square miles. The slopes are steep, in many places, being precipitous cliffs rising from the river. The tributary streams present the same characteristics. Many of them run at right angles to the main stream, and generally parallel to each other. While the valley proper, and the valleys of the tributaries are not wide, the total gives a large area. The slopes of these, being steep, allow rapid drainage into the main stream of any precipitation. Thus rapid drainage is also aided by the denudation of the valley slopes of their timber growths. Twenty years ago a dense and continuous forest covered these slopes. At the present time there is little timber standing.

The character of the underlying rock formation of the main river and its branches has produced a nearly regular decline from the highest source to the termination at Pittsburg. The only irregularities being a few rapids, with no pool of sufficient size to allow a slow current or storage of water. As a result of these conditions, any unusual amount of precipitation causes the washing of any portable materials deposited on these slopes into the main stream, and then carried rapidly to its mouth.

These slopes are not densely populated. Sixty towns, rang-

ing in size from Johnston with 43,000 and Jamestown, N. Y., with 27,000, down to small hamlets with less than 1,000 people, all having an aggregate of 277,600, represents the urban population. Of these 60 towns, 16 have a population of 5,000, and 8 of 10,000. The average per square mile of this urban population is 24. Of these towns, all but a few are rapidly increasing in size, and we may fairly assume that all the towns of 3,000 are partially sewered, and all over 6,000 are sewered.

To this must be added the rural population, not great in this case, but regarding sewage contamination of a watershed, a dangerous one. It has been demonstrated by dangerous and numerous epidemics of tyhpoid fever, that the rural methods of disposal of human excreta readily allow, in valleys of this type, their rapid washing into the main stream at every freshet, particularly in the spring and fall.

Comparing this average of population with that of the sources of supply for other cities, it is small, and far removed from the Brilliant "intake," but we will now show that it is dangerous.

With this large area of drainage and possibility of sewage contamination, the next question suggested would be, Does this river and its branches possess the characters or offer the conditions that would allow a "self-purification" of its waters?

Two factors are necessary to allow this to take place, and these are just the opposite of those popularly concieved to be necessary to procure "purification" of river water. It was early supposed that rapidly flowing water, particularly when the bed was stony and "riffles" were abundant, by coming in contact with the air, purified itself by oxidation. This theory had for its proof the disappearance of chemicals placed in the water at some given point, when the water was examined at some point below. This lessened pollution was nothing more than a diminution of quantity from dilution with the water of tributary streams entering below the point of entrance. This method of analysis of this power did not include that most dangerous of all the contaminating substances of river water, *i. e.*, the bacteria. Dangerous not of themselves, but of their consequences when introduced into the human body.

At the present time bacteriologists and sanitary engineers do recognize a "self-purification of river water." This is brought about by two causes, (1) sedimentation in pools, either slow running or stagnant sufficient to allow the time factor to act; and, (2) the destructive action on parasitic or disease germs by the harder and more robust taphrophites or putrefactive bacteria of this still water.

Extending our examination of the Allegheny valley, we will see that these conditions do not exist. From the source of the river proper, as well as the contributing streams, it is a rapidly moving body of water. The whole course shows a rate varying from a mile in a few minutes for small distances, to an average of two miles per hour in low water, and six to eight in flood time, for the whole distance. It is easy to deduce that the quiescence and time factors are absolutely wanting. As estimated by the United States Engineers, any sewage flowing in the stream at Oil City would reach the Brilliant intake in 15 hours in flood time, and three days in low water. Pools or mill dams are not found that would allow the water to become quiescent for more than a few hours.

These cañon-like valleys of this watershed have determined the beds of the rivers flowing through them, for examination of all them show no sand bars, mud beds, or accumulations of water foliage, but a stony bed, in many places polished smooth, or covered by polished gravel and smooth sand. Both these conditions are eminently favorable for the swift transportation of polluted material from the highest source, without hinderance of purifying obstructions, to the mouth of the river.

With this not reassuring prospect, it is clear that the probabilities of contamination are not removed. As referred to before, while the urban and rural populations of the watershed are not large, either in the aggregate or to the square mile, yet it is evident, on account of the steepness and the absence of obstruction on the slopes, the stony and unobstructed river bed, with the rapid rate of flow of the river, that the water at the Brilliant intake must be in the same condition as if it were from a small watershed, densely populated.

Coming now to the third division of our analysis, let us consider what this sewage means, so far as its danger to human life is concerned. There are many substances thrown into sewers that are contributing causes of disease, but not necessarily exciting causes. These are usually of a chemical character, either acids, alkalis, or salts. Examples of their dangerous characters to lower organisms are found in the destruction, either partial or complete, of fish and other aquatic life in streams contaminated by washings from draining vats of mills, from coke ovens, and coal mines. That the human animal can acquire an immunity to these is evident. This immunity is partially due to precipitation and dilution, is no doubt true. We are all familiar with the intestinal disturbances caused by drinking a so-called "strange or unusual" water, particularly if from a district where reasonably pure water is in habitual use to one markedly polluted.

It would be a very rash and unscientific statement to assume that these chemicals do or do not cause intestinal disturbances in man. It is clear to most minds that the burden of proof rests on the negative. That this contamination predisposes to these intestinal troubles, thus allowing specific causes of disease to act, no one excepting those biased will deny. The normal resistance of the body may be so over taxed, that so slight a cause as these chemical contaminations may be sufficient to precipitate an actual disease condition.

Leaving these, we now must consider the substances entering sewers that are derived from animal life. These, so far as life is concerned, must be regarded as the most important. Time will not permit any but a study of those derived from the human body. A consideration of these secretions, their contents, sources, and the conditions present or absent that would limit, inhibit or increase their various characters, is not a pleasant task.

As noted before, the ignorance and indifference of the layman, and the carelessness of the professional man, allow the easiest and most convenient method, *i. e.*, "dumping into the sewer," to be one followed in disposing from human habitations, of anything and everything of a noxious and unpleasant character. As in the use of privy-vaults in an earlier era, and in less populated

districts, the sewer now occupies the much desired location of that place, for, out of sight, out of mind. Nor must we be too harsh, for often custom and absence of opportunity, as well as other restrictions, do not permit of any other method. As a result of these, we find that the water entering the river from the city and town sewers, as well as that from the overflow and flushing of the country privy vaults, contains the most undesirable nauseating substances known to the average human conceptions. As scientific men, the term dirt is relative. We use the term dangerous rather than dirty.

Of the dangerous substances, then, entering the sewers, those from the human body could include all that could possibly be contaminating agents, or the specific causes of disease. Of these we can consider fecal matter, urine, sputum, vomitus, and discharges of various kinds from all surfaces and cavities of the body, normal or diseased.

It is an open question as to the amount of trouble caused by the soluable matter of these secretions when in river water. They represent chemical substances, derived from bacterial action or rearrangement from metabolic action of chemicals ingested, and could be placed in that uncertain class noted first. From an esthetic point we do not care to know that our drinking water contains the soluble matters of these secreteous from the inhabitants of Claremont, and of the mills, and cities in the valley above us; but the fact that their chemical characters and reactions are no different from those formed by chemical action in any of natures living laboratories, as well as that other fact that life cannot exist without them, or their derivatives, must cause us to lay aside the esthetic idea for the true and nobler scientific conception. We have to face the inevitable and know that no other form of water is available, unless we use water absolutely without salts, *i. e.*, distilled water. This is impracticable as a municipal problem.

Dismissing, then, this aspect of the question, the solid constituents, particularly the living, should be considered. That these secretions contain living bodies of small size was one of the first discoveries of bacteriology. That many of these are

disease producing germs is easily shown, *e. g.*, typhoid stools contain myriads of the B. typhosus. Blanchard, as early as 1881, demonstrated that 25% of typhoid urine contained large numbers of this bacillus. Heuppe (1886) and Richardson (1899) also demonstrated the same condition, the per cent. varying from 20 to 80. It has also been shown that this organism may persist long after the patient is convalescent. Personal observation has demonstrated this B. in abscesses several months after recovery. Other secretions may be shown to contain them also. Of the scores of cases of this disease among the inhabitants of this watershed, few only have these secretions sterilized; the remainder enters the sewer.

Another organism, a normal inhabitant of the intestinal tract, a criterion of sewage contamination, can always be demonstrated in Allegheny River water. While this is generally a saphrophyte, its close association with the typhoid must not be forgotten.

When we know that the sewer is the receptacle of the sputum of tuberculosis, the secretions of the throats of diphtheria, the secretions and wash water of scarlet fever, smallpox, the feces of dysentery, and other intestinal inflammations, and the remainder of the pathological states of the human body, the possibilities are not lessened. Fortunately the causes of many of these disappear with the disappearance of their particular nutrition. The uncertainty surrounding the intermediate as well as primary habitat of many of these disease producing factors, would of itself, without proof, cause the water so polluted to be regarded with suspicion and caution. The amount of organic matter in water often determines the presence and continuance of the disease bacteria in it. Chemical analyses show that this water contains sufficient to act as pabulum, for an indefinate time, under existing conditions, as noted before.

Not enumerating any more of the bacterial possibilities or contaminations, we can now examine those conditions existing in this river that inhibit or exaggerate the virulence of these particular bacteria shown to be contained in it. As stated earlier, the two conditions in "self-purification" are quiescence and time. We have seen that the Allegheny River does not allow either.

Not only does it not allow them, but the rapid current and smooth bottom carry along with the bacteria their associated food products. The only inhibiting influence these conditions could have on the bacterial contaminations, is that it rushes them along at such a rate that it may prevent a multiplication; it does not actually decrease the number. Relatively they should be decreased by the dilution of contributory streams, but the rural population has already contaminated them. This allows the pools at the level of Pittsburg, as now formed by the Herr's Island Dam, to recieve an enormous amount of bacteria with a corresponding amount of organic matter for nourishment.

The length of time required for bacteria of this class to die out here, arises as a possible factor. A comparison of this time, with the length of time elapsing from their entrance in the river to their distribution in the service pipes is important. As is well known, the life of a bacterium varies with the environment. Of the intestinal bacteria enumerated, few would die out in less than six days under favorable conditions. These favorable conditions do not exist, as the time elapsing from entrance of sewage at Oil City to distribution in Pittsburg is less than that. Including the contaminations lower than this, it is improbable that this factor has any bearing.

The consumption of 50,000,000 gallons daily, compared to the size of our basins, would allow such a small time for self-purification, that they can be dismissed as having little or no influence; not enough to lessen the evil.

It might not be amiss here to review the results of actual examinations made of the Allegheny water. In making a bacteriological examination of water, three varieties of tests are performed: First, The number of B. to each c. m. are estimated. This is called the "bacterial count." Second, The bacteria are isolated and identified. Third, Fermentation tests, to show the presence of B. from the intestinal tract. Usually, on account of the long time required, the second, excepting for certain bacteria, is omitted. The "bacterial count" does not indicate anything specific, yet, if associated with the "fermentation test" and the "identification test," it has a cerain value.

Tests made by the Filtration Commission show the number of bacteria at the Brilliant intake to be as follows, picking out a few months only:

October, 1897	49,500
November, 1897	52,312
December, 1897	5,100
January, 1898	16,486
May, 1898	16,700
August, 1898	18,300

Tests made at my laboratory, were close to the above *e. g.*:

July, 1901	14,010
August, 1901	19,600
September, 1901	46,310
January, 1903	20,100
July, 1903	41,000

While these extend over a larger period, they show a fair average with those of the earlier tests. Counts made by the Filtration Commission, of water from a city tap, show a decrease of from 10 to 50 per cent. only on corresponding waters—a reduction so small as to show the inefficiency of the basins in use as purifiers.

The Filtration Commission also, under the direction of Chancellor Holland, conducted a series of fermentation tests. These were performed by Dr. Eug. Wasden, of the Marine Hospital Service, and were made according to the method of Theobold Smith. Of 15 tests, 12 were positive, showing the presence of the intestinal bacteria. During the months noted before, in my laboratory tests of a similar character were performed. Eighteen tests were made, and 16 gave positive results. Here, as in previous years, the averages are about equal.

Coming to the actual identification of bacteria in water, it is of interest to note that no method has been devised to successfully and positively identify the B. typhorsus in river water, that can be put in general use. This is partially brought about by the great dilution of the water, as well as morphological changes. The inference that they are present can safely be made from the following: (1) The presence of

associated intestinal bacteria, particularly the Colon group. (2) The association of epidemics with the use of this water. (3) The association of epidemics with known contaminations of the sources of the water supply, the water being the only infection carrier possible.

That the last two have been repeatedly demonstrated, I need not refer to again. The first is a long, tedious test, but Fuller and Johnston, investigating the bacteria in the Ohio River (Cincinnati, O.), found 42 different types of bacteria, included in 13 groups. The majority of these were supropnites, yet they found six to be pathogenic, including five of the intestinal bacteria. They also found a group having the morphological characters of the typhoid, yet not responding to the "Widal Test."

Here arises an important question: Is it probable that a bacterium may acquire new and different biological characters in an unusual and unnatural medium, *e. g.*, the transference of typhoid B. from feces to river water? This is no doubt the case. At present we have to base our results on inferences and deductions alone. If this be true, then the bacteria that are the most dangerous may take characters that are so foreign as to interfere with their identification, but not lessen their virulence as disease producers. This may explain the difficulty of identification of the B. typhosus.

The last point to be considered from the bacteriological aspect, and from the economic side, the most important is: Can these conditions be remedied or removed? We can answer them as follows: Removal or conversion of the soluable substance contained in the Allegheny River water is a question for the chemist and physiologist. We are concerned with the removal of the living organisms. Not only with their removal, but with having it accomplished without adding anything to the water of a character dangerous to health, either predisposing or exciting. We feel that this can be accomplished by only two methods, *i. e.*, first, by the addition of some substance which, by a mechanical change and chemical reaction produces precipitation of albuminoid matters, and the removal of these products; second, by the use of a filter, being so composed of sand as a filtering medium

that the water in passing through by gravity is freed from its insoluable matter, including mud and bacteria.

The construction of these filters is not pertinent to this paper, only so far as their efficiency is concerned. Two objections have been made to the first type; (1) the amount of chemical cogulant alum, required to the varying percentage of lime in solution in the river water, with the difficulty of regulating the supply of coagulant so that it is all precipitated, and thus prevent it rendering the water unfit for commercial or domestic purposes; second, the varying and low bacterial efficiency.

In considering these objections to mechanical filtration, the first belongs to the physiologist. Without discussing it further, it is the opinion of the majority that the quantity of lime present, on account of the varying conditions of rain fall, snow, seasons, etc., in our river water would necessitate expert technical skill on the part of those operating the filter, so that there would not be more alum introduced than used, thus preventing our water from containing an excess of this salt. That this water would be a dangerous one, if such conditions existed any great length of time, as a predisposing cause of disease, is admitted by physicians. The proof here, also rests on the negative.

So far as the bacterial efficiency is concerned, it represents an average of 97 to 98%. Two difficulties that, so far as shown, have not been remedied, are, that during the periods of greatest bacterial growth in the river, the per cent. of efficiency remains the same, and that during the periods of greatest turbidity, the amount of lime present is not in proportion to the turbidity, and thus the coagulant power and bacterial efficiency are decreased.

These two conditions, from the point of the bacteriologist, are so easily increased by natural causes, as well as by ignorant and careless manipulation of the filters, that they do not regard it as the solution of the problem.

The only thing left is to consider the gravity, or sand, filter. The objections to its use are not due to the bacterial efficiency. With the average efficiency of 99 per cent.; and, during the months when the raw water contained the largest number of bacteria, reaching the remarkable efficiency of 99.96 per cent., lit-

tle more can be desired. It is estimated that the average efficiency is even greater than these figures, for it has been found that air bacteria often grow in the drains. These B. are harmless, but decrease the per cent. of efficiency actually reached. (See Report F. Com. of Pitts., 1899.)

No chemical being used, the water does not possess the disadvantage possible to those filters using alum coagulents, as a factor in disease. In fact, the bacterial efficiency of the sand filter depends on its construction. The problem, then, rests on the engineers in care of its construction. Its manipulation after construction is of such a character that there is not the probability of the varying natural conditions affecting it as in the mechanical filtration.

The cost, manipulation, possibility of extension, and other problems have been carefully considered by experts, and these, with the results noted, undoubtedly point to the sand filter as the safest and most efficient filter possible for a large community like Pittsburg.

In conclusion, we feel that the following conditions confront us:

1st. The water supplied to Pittsburg is seriously objectionable.

2nd. That the greatest of these objectionable conditions is the presence of disease producing bacteria.

3rd. The natural conditions existing in the Allegheny watershed will not allow this objection to become lessened or removed.

4th. With the increase of population of the valley, it will be increased in proportion.

5th. It is possible to remove this objectionable feature by filtration.

6th. That properly constructed sand filters, with competent manipulation, will be the means of saving each year, from 240 to 350 lives from one disease, typhoid fever, alone.

7th. That, as residents of Pittsburg, it is our duty to present these facts to the people and to the governing bodies of Pitts-

burg, without fear or favor; and that we demand, as that right, our legislative bodies, with all possible speed, by laying aside personal ambitions and party strife, will correct this great menace to our health and lives, by installing this filtration plant and furnish us with pure, wholesome water.

DR. INGRAM—If any one here is interested in the methods of making these analyses, I shall be glad to show them at any time.

MR. CAMP—It is unfortunate, gentlemen, that we cannot discuss these papers as presented, but time will not permit it. I shall, therefore, call on Dr. Matson to give us his paper.

FILTRATION FROM THE HYGIENIC STANDPOINT.

BY DR. E. G. MATSON.

I must confess that I have not prepared any paper for to-night, and all I shall say will be comprised in a few rather desultory remarks. I think it is a good thing for us to know and learn about this very important subject. I think we need to meet here to discuss the thing together as physicians and engineers, so that the one may not forget what is best understood and felt by the other. Of course, from the standpoint of the engineer, the most important thing, I suppose, is to get the water up the hill so that it will run down again; but the physician or bacteriologist is more particularly interested in the quality of the water, and whether it contains matter that will endanger the life of the people. Now, since our efforts are directed to combating disease, we need to understand the way in which disease spreads, and in this there is no general method which will apply to all. For instance, there is one method for combatting smallpox, another method for combatting typhoid fever, and still another method for yellow fever. These are all very useful and important, but of course we cannot cope with all diseases in the same way. We might compare cholera with typhoid fever, or measles with smallpox, and there would be some resemblance in the methods employed. It is a common belief, for example, that the introduction of a sewer system in Havana has put an end to the yellow fever there. This is a mistake. While the suppression

of this disease has, I think, been the most absolutely successful attempt that has been made to suppress any disease of this character—because it has simply abolished it altogether—yet it has not been by sanitation; but it has been done by a recognition of the fact that this disease is carried by a certain breed of mosquitoes, and the methods taken to combat this disease have been along that line. In the same way, we cannot suppress typhoid fever by simply removing putrescent matter, because this putrescent matter does not cause typhoid fever. Neither can we suppress smallpox by simply cleaning the alleys, although this plan was advocated last summer by some of the Pittsburg newspapers; but that was only one of the few instances where the newspapers made a mistake.

But there are two diseases I shall mention particularly this evening, and they are cholera and typhoid fever. In speaking of these two diseases in particular, I do not mean to assume that there are not other diseases destructive to human life which are due more or less to an impure water supply, and which may be greatly lessened by an improvement in the water supply. Now, these epidemic diseases, familiar to all of you, which go from one person to another, start always by some particle coming from a person who is sick and reaching another person susceptible to that disease, while it is in an active condition, or an efficient state. Of course, if we can say that the particle from the sick person reaching the well person is alive, we have a germ theory, and the germ theory was developed long before microscopes were made powerful enough to discover the tiny organisms which we hear about so much in these days. When we think of the manner in which these living particles, or active particles, are transferred, we bring in the germ theory, and so account for the infection of a well person in a multitude of different ways. It may be carried by the garments, or by means of some raw article of diet; or it may come from the water supply, which is one of the articles we take uncooked, or it may come through the milk supply. Consequently, if these particles can remain alive during the period from the time they leave the sick person until they reach the person who is well there is a likelihood of the well person being in-

fected with that disease. Then again, these particles of germ carrying material remain active in milk and water and such media unless something is done to destroy that condition.

Now, the reason why typhoid fever and cholera are so readily carried and so readily infect a river water supply is this: The water supply represents the drainage of a certain area or watershed, always more or less densely populated, and must contain a greater or less quantity of human stools and human urine, which constitute the principal means of transmitting typhoid fever germs, cholera bacilli, etc. In some other diseases, it would be discharges from the mouth or throat, such as diphtheria; and in the case of smallpox it would be all the excretions. The typhoid fever particles are, therefore, generally disseminated through the water supply because they are most likely to reach it and remain alive in the water for a considerable length of time. At the same time it is quite certain that they do not actually multiply there—but the bacteriological problem has been considered this evening already, and on that account I shall not go into it at all. I shall simply be satisfied to point out this fact, that typhoid bacilli and cholera bacilli are carried by streams of water, large or small, to persons who have never had these diseases at all, and who are consequently likely to get them.

There is another thing in these diseases, and that is that some part of the body, susceptible to that germ, shall be reached by the active particle; or, in other words, that the germ shall reach a field suitable to its operations. This, of course, is not the same in all diseases. In some diseases it is the throat, and in others it is evidently the intestinal tract, as in typhoid fever or cholera. In others it must get into the blood itself.

Now, while we know that the water supply can carry those diseases, we do not assume that there are no other means by which they may be disseminated. The fact that typhoid fever is a common thing, however, makes it natural for people to blame the water supply as being the chief trouble, but there is no reason to believe that it might not be present to some extent with a good water supply. As I have mentioned, it may be due to the milk supply or at certain seasons of the year the active particles may be

transmitted by flies or other insects. For instance, in military camps, where the housekeeping is very bad, these flies and other insects may be a more important means of transmitting the disease than the water supply itself. Now, when we come to consider the question of evidence as to the transmission of these active particles, which has already been touched upon, it goes to show that typhoid fever is actually conveyed in the water supply—and the same is true in cholera—and we have a considerable amount of it. It is, however, rather in the nature of inductive evidence than positive. In the first place, one would expect, from the immense number of people the water supply reaches, that the results of that infection would over-ride everything else. If everybody also had an infected well that he drank from he might take typhoid fever just as surely from the well as from the river water supply, and to bring one of these defects to an end might make no difference in the statistical results. The only reason why we can expect to show statistically that a pure general water supply will make a difference in the amount of typhoid fever present in any community, is because there is no community with sense enough to have a water supply, in which there are enough other causes to maintain the epidemic, such as bad housekeeping, military camps, etc., etc. I might add that we have a great many facts to show that both of these diseases are conveyed through water, and that typhoid fever is largely due to the water supply. For instance, where it can be shown that on a particular day or within particular days this water (which was subject to contamination as ground water supplies usually are) became infected through the disposition made of contagious stools from a typhoid fever patient, and that on a later date, corresponding to the incubation period of typhoid fever—about two weeks—a number of persons drinking that water were taken with that disease, and that other persons living in the same neighborhood and not having occasion to drink that water, did not have the disease, then we can pretty safely assume that the active particles have been carried by the water.

In the case of the river water supply, how do we know that typhoid fever bacilli are in it? We do not, for instance, find the

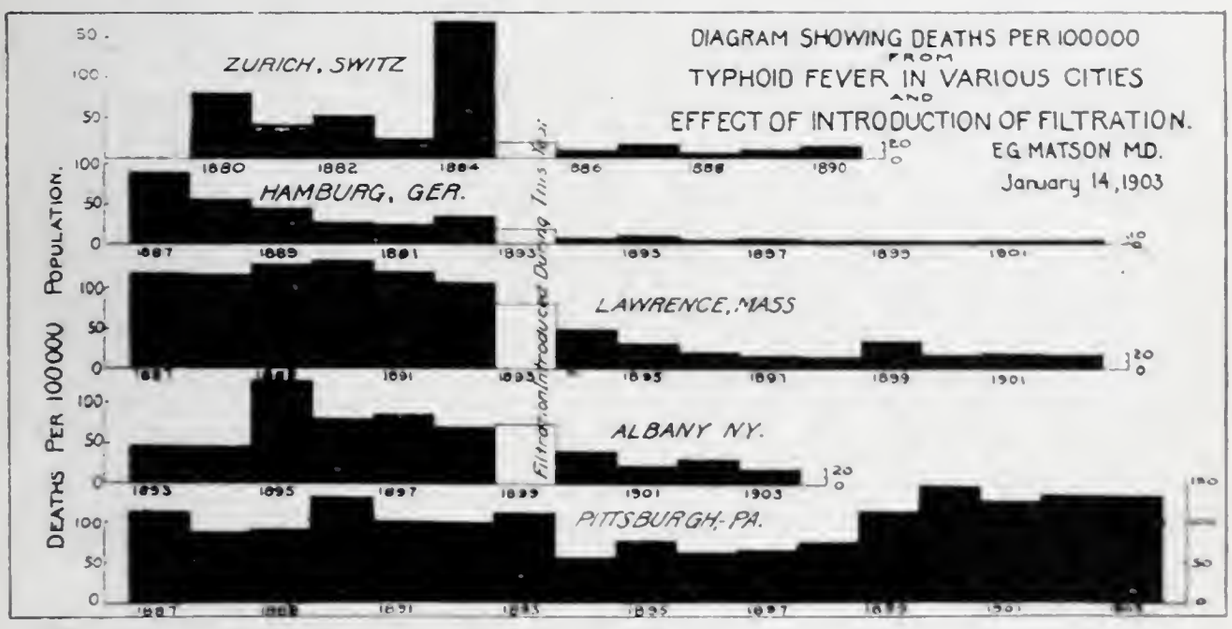
drinkers of that water experiencing such intense epidemics as are sometimes caused by well water in a farmer's family. In the city, we have seldom more than one person in the family who is sick at one time, and even when we make all allowances these results are not nearly so intense or severe as in smaller epidemics, where nearly every person is affected. There is one way in which we can be very certain that there are typhoid bacilli in it—if we saw them put in the river—and the only thing you could have any doubt about would be whether they remained alive. You certainly would believe they were alive until a long enough time had elapsed to exceed the number of days that experience has taught us they would live. We are certain that the stools and urine from typhoid fever patients reach the rivers, and since we know perfectly well that the rivers are the sewers of the population above us, we know they contain everything that the population throws away. We are certain that the stools of typhoid fever patients contain the infection of this disease—we call it typhoid fever bacilli—we know it contains that. We know of dozens of places where it must unavoidably reach the river. Whether it enters by means of ground water, or however it enters the river, it will carry some contagion—the same is true for the many rills, and creeks, and tributary streams running into the river all the time—and from there be pumped into the reservoir. When it comes to a question of examining all the bacilli that are to be found in water where there are 5,000, 10,000 or 50,000 to the cubic centimeter, it is very difficult and tedious. It is a question as to what it is possible to determine where there is such a multitude of life, and it is necessary to identify them one by one after the slow processes of the bacteriologist. You will see that it is almost utterly impossible to reach positive conclusions that the water is pure or that it is otherwise by analytical methods alone.

I also want to speak somewhat of the statistical value of what is to be effected by a pure water supply. All these epidemic diseases tend to limit themselves, because while it is true that people may have typhoid fever two or three times, and in every epidemic there must be more or less mortality, yet practically all

the survivors are immune. Consequently in the case of supposed infected river water, every one cannot get the disease at the same time, for the reason that great numbers of them have already had it. It is also true that many people are not susceptible to typhoid fever at all. I think I am not, because I drank Allegheny River water for a great many years. In this city, for example, we would not find an equal distribution of typhoid fever. Why should we? Because in some localities there are local channels for the spread of this disease, while other neighborhoods are deficient in this respect. Another thing is the difference in the population which exists in the different wards, some being largely foreign, etc. There is also a susceptible age for typhoid fever. That age is a little younger than most of those I see before me. The most susceptible age is from 15 to 25 years, and after 35 you grow less and less susceptible to the disease. Consequently there are quite a number of young people who take it. If we look at the typhoid fever statement showing the number of deaths from that disease in Pittsburg—we can go back to about 1873—you will find that typhoid fever has been just about as good an indication of the prosperity of this city as anything else—the price of pig iron, for instance. When the times are good, typhoid fever is up, and when times are slack the number of cases falls. That is one consolation in slack times, anyhow. The real reason is that in these times of prosperity, like the one which has just now apparently passed away, there is a great inrush of new people, and most generally young people. They come from everywhere, and they come from abroad, and they come from the rural districts. When they come from abroad, they generally come from places where typhoid fever is not so prevalent. It is a fact that most of the highly civilized countries of Europe do not suffer from typhoid fever as we do. It is really getting to be an American disease. Consequently we always find that the foreign born are numerous among the list of deaths. Typhoid fever is not very common in England, relatively speaking: nevertheless, the Englishman suffers terribly when abroad.

When we look at the statistics of foreign cities, see the amount of typhoid fever there, and compare with the amount we

have here, we can readily see the result of the great sanitary works which exist on the continent. If the general water supply is carrying typhoid fever, every channel of infection in neighborhood or locality where that supply reaches is made more or less active. Perhaps many of you are familiar with the results of having a privy vault and well located in loose soils. It may be perfectly harmless and remain there for years; but after a while typhoid fever comes along, or in some way or other typhoid fever infection comes into that vault, and then it is like a powder train. So it is with the milk supply if contaminated water is poured into the milk, as it may be, or perhaps as a milkman once explained in a suit that he put ice in his milk to cool it. On the other hand, if the farmer goes into the city and drinks some of our water supply—supposing that our water is bad—and after going home he gets typhoid fever, he can get even with us by having some of his stools go into Pine Creek, or some other stream flowing into our water supply. Infection of the general water supply keeps these local conditions active in disseminating the disease.



I have made here some very rude diagrams which I am not sure that you can all see well. The first one indicates the number of typhoid fever patients in the city of Hamburg. The height of these columns corresponds to the number of deaths, with reference to the population. That city has grown very rapidly—perhaps as rapidly as Pittsburg has grown The chart starts with 1887 and it

concludes with 1902, the last report of the city. The amount of typhoid fever in that period was not as great as we are accustomed to in Pittsburg. We seldom go below six deaths in ten thousand. Hamburg was the only large city in Germany, France, or England which had a water supply like our own, pumping the water just as it was from the river a little above the city. This year (indicating 1892) was a great cholera year. Then they hurried up and got their filtration plant built, and they got it built in this (indicating 1893) year, when the number of deaths ran down to 116. You will see that it was introduced during that (indicating) year, but you will note that in the subsequent years there was a very great decline, until now typhoid fever is less common than in almost any other city.

The second chart shows the results after the filtration year. I made this chart—as Number One starts at this year—because it appears to decline before the filtration is put in. Hamburg is of considerable interest in this connection, because it represents a large city, where, no doubt, the statistics are carefully and accurately kept. In this city a very large and improved modern sand filter has been placed. In other cities the sand filters have undergone a period of development, and there is no opportunity for showing the sharp change. The second chart also shows the results at Albany. The second diagram represents a plant which has been in operation. It happened that the city had about 100,000 people at that time. Lawrence is also shown here—a city that has been very much affected—and covering the period of this year.

Mr. James O. Handy then read paper on "The Art of Water Softening."

WATER SOFTENING.

BY JAMES O. HANDY.
Chief Chemist of Pittsburgh Testing Laboratory, Lim.

Part I. Introduction. Damage Done by Hard Water. Incentive to Study of Methods of Softening Water.
Part II. Growth and Present Development of the Art.
Part III. Chemistry of Water Softening.
Part IV. Municipal Water Softening Plants. Southampton, England; Winnipeg, Manitoba.

PART I.

Introduction.

Hard water owes its soap-destroying and boiler-incrusting properties to the compounds of lime and magnesia which it contains. These compounds have been dissolved by the water as it passed through fissures in limestone. In a sandstone or granite country the water is soft.

While discomfort and inconvenience result from the use of hard water in the household, the greatest trouble, expense and danger come from the use of hard water in steam boilers. In a coal producing district, steam users have to contend also with the corrosive effects of acid waters, from the mines and washers. Many well waters contain corrosive substances such as free carbonic acid and certain magnesia salts.

The troubles caused by acid waters are in most cases more acute than those produced by scale-forming ones, because in the former case there is actual destruction of parts of the boiler itself. Boiler incrustation is also a very serious matter. The danger of explosion through sudden access of water to overheated surfaces is always present. The waste of fuel is enormous, as the scale is a more or less perfect insulator, according to its composition and density.

The bill for boiler cleaning and repairs is extremely heavy when a hard water has to be used. These facts are in general well known, but they have not received the attention they deserve.

The railroad companies have been the greatest sufferers and their officials have been most active in investigating and applying relief wherever possible. The Railway Master Mechanics' Association has had committees working on the matter ever since 1873. They found that in some hard water districts, the flues in locomotives had a record as low as 18,000 miles, and lasted only seven months. Fire-boxes were used up in fifteen months to three years. In districts where soft water was available, flues made as high as 300,000 miles, and lasted as long as eight years. Fire-boxes 13 years old showed no signs of weakness.

The use of hard water in locomotive boilers meant not only heavy expense in renewals of wornout parts, but such loss of service from engines undergoing repairs as to mean a crippling of the road.

The fuel consumption of locomotives with freshly cleaned boilers was found to be far less for the same work than was the case with engines having scale-covered tubes.

Impelled by considerations such as these, the railway men advocated most thorough search for soft water supplies. In cases where only hard water could be had, purification by chemical treatment was recommended as a means of relief.

It was soon recognized that the cheapest and most efficient chemicals for water softening were lime and soda ash. It was only natural that attempts should first be made to secure the benefits of chemical treatment by simply pumping the solution into the water flowing to the storage tanks or even to introduce chemicals into the water in the locomotive tenders.

Both of these methods when skilfully managed, gave some degree of satisfaction and economy. It was evident, however, that neither the storage tank nor the locomotive boiler was the proper place to purify the water. It should be softened and clarified before it entered the wayside tanks.

Crude, two-tank purifying systems have been succeeded by

compact machines which *continuously* soften, clarify, and deliver the water into the service tanks. Of about 100 softening plants in use on railways, over three-fourths are of the continuous type.

In the following sketch of the growth and present state of the art of water softening, I have endeavored to place the credit for successive improvements with those who appear to have been the first to suggest or apply them.

The machines or systems now available for water softening purposes are carefully compared, with the idea of showing what is novel and valuable in each plan.

The author hopes that his endeavor to treat the subject impartially has been successful. If, however, injustice has been done inadvertently he will gladly make amends.

PART II.

The Art of Water Softening.

Cavendish[1] discovered in 1766 that the addition of lime water to certain natural waters caused the deposition of carbonates of lime and magnesia to take place.

Thomas Henry[2] in the latter part of the same century proposed to soften hard water by the use of slaked lime or hydrate of lime.

Dr. Thomas Clark, of Aberdeen, in 1841 patented a method for making use on a large scale of the lime process for water softening. For determining the amount of lime required he used the alkalinity test, and for ascertaining whether enough lime had been added, the silver nitrate test was applied to the treated water. These tests are in use to-day. Clark also is credited with suggesting the use of a standard soap solution to determine the total hardness of waters, their soap-destroying power being quite an exact index to the total amount of lime and magnesia which they contain.

While very perfect chemically, Clark's water-softening process was carried out very crudely when regarded from an engi-

1 Fischer: Chem. Tech. des Wassers, 1880, p. 262.
2 Archbutt: The Softening of Water, Eng. News, Dec. 22, 1898.

neering standpoint. Masonry tanks set in the ground served for making limewater, for mixing, and also for clarification. The time allowed for softening was from twelve to twenty-four hours, and the cost for treatment was unnecessarily high.

Furthermore, the process had its limitations. It could only be used with perfect success on hard waters, in which the carbonates of lime and magnesia were the principal impurities present. Sulphates, chlorides or nitrates of lime or magnesia, while capable of destroying soap and causing many of the troubles due to hard water could not be removed by Clark's process.

Later on, in conjunction with Porter, the method of handling these more complex hard waters was taken up with some success.

In Germany, F. Schulze in 1876 suggested the use of lime and soda for softening waters containing both bicarbonates and sulphates.

THE PORTER-CLARK PROCESS.[3]

There is not much data available as to the extent to which this process was put into actual use. The system consisted in the treatment of water by means of a solution of lime or soda, or a mixture of the two. The chemical solution was usually forced into the mixing tank by the pressure of the air expelled from a metal receiver by the incoming water.

When the reservoir tank was full, the water was allowed to pass away through a filter press.

The system was ingenious but very expensive to install and operate. It must have required constant attention. If the slightest air leak occurred, the chemical feed was no longer in the proper proportion. With so little settling capacity the cleaning of filter presses must have required constant attention, especially with magnesian waters. The L. & N. W. Ry. Co.,[4] softened by this process 7,000 gallons per hour at Camden Town. The hardness was reduced from 18° to 4° while the water was under 60 pounds pressure.

The work of certain French and German inventors followed and improved on the processes of Porter and Clark. The engi-

3 Delhotel: L'epuration des Eaux, p. 309.
4 Fischer: Chem. Tech. des. Wassers, p. 267.

neers of the French railway "La Compagnie du Chemins de fer du Nord," installed their first softening plant in 1861. It differed from the Clark system only in the use of milk of lime instead of lime water. Large masonry reservoirs were used. No labor-saving appliances or means for exactly controlling the treatment were employed.

Their later type of softening plant consists of elevated steel tanks with means for mixing the chemicals and floating draw-off pipes for removing the softened water. Filters are used to effect final clarification.

It soon became evident to the engineers working in the water-softening field that the elements of heavy expense were labor and interest on investment in great reservoirs, etc., necessary for the carrying out of the intermittent process of purification.

The Clark process required, according to Rideal ("Water and Its Purification") two 40,000 gallon tanks for lime water and three 300,000 gallon settling tanks for a daily output of 250,000 imperial gallons. This meant a tank capacity of nearly 1,000,000 gallons in order to secure an hourly output of 10,400 gallons. A modern softening plant with a tank capacity of 240,000 gallons, softens 60,000 gallons of water hourly and is, therefore, twenty-four times as efficient as the Clark system.

There was great incentive to devise a simpler system of softening. If the operation of softening could be made continuous, the gain would be great.

It seemed necessary simply to have a uniform chemical feed, a thorough mixing of chemicals with the water, and sufficient time for chemical reaction and proper sedimentation. Easy as this appeared, it has taken many years to satisfy all of these requirements.

Berenger and Stingl were, we believe, the first to construct continuous softening plants. They were only moderately successful, but they were pioneers in the field. Their first apparatus[5] consisted of a reagent tank, in which the chemical solution was prepared by hand, and then continuously mixed with the hard water flowing to a mixing tank. Here the mixture passed down

5 Rideal: Water and Its Purification, p. 219.

through a central pipe, striking a conical obstruction on the bottom. This deflected the stream side-ways over the entire cross section of the tank and its velocity was suddenly diminished, allowing some sediment to deposit. The clarification, and probably the chemical reaction also, were very imperfect. Filters were used, but they were soon stopped up, and proved very difficult to clean.

By enlarging and changing their apparatus Berenger and Stingl tried to overcome their difficulties. They were working on the idea that change of the direction of flow was the most important influence in assisting the clarification of the turbid mixture produced by adding chemicals to hard water. They next used a series of settling tanks[6] or "decanters," each one being of larger section than the one preceding, and each one having a sludge cock at the bottom. The incoming mixture passed by a pipe to a point just inside the opening of an inverted cone supported on the bottom of the tank. The cone was of such shape and size that it reversed the flow of water and threw it outward. This had the effect of diminishing velocity and allowing sludge to settle to some extent from the sides of the stream, past the cone, and down to the point of draw-off.

This plan effected much more perfect clarification than before, but it was still necessary to filter the water, and results were otherwise imperfect, showing that the conditions governing continuous and perfect softening had not been fully apprehended.

Pichler and Sedlaeck[7] followed with an apparatus evidently designed to meet the objection which had been made to the numerous tanks required in Berenger and Stingl's system. They made a machine consisting of concentric cylinders, the water passing up and down in annular spaces of increasing area, and finally out through an annular filter into a circular collecting canal. The sediment collected in the cone-shaped spaces terminating each cylinder.

The use of an annular filter and circular collecting trough seems to have originated with these inventors and represented a distinct advance in the art of water softening. The rest of the apparatus,

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6 Delhotel: p. 308.
7 Delhotel: 327.

while apparently simple, was actually complex, being costly to construct and difficult to operate. The sludge had to be drawn from all the compartments through a perforated pipe by one cock, and naturally the draught was very uneven. These inventors were also impressed with the idea that change in direction of flow was an important thing.

Gaillet and Huet[8], after the experience gained in constructing Berenger & Stingl's apparatus, devised several improvements and constructed machines of their own. They built a high tank, filled with 45° shelves of V shaped section. These were fastened alternately to opposite sides of the tower, so that the water to be clarified, when introduced at the bottom, rose by passing back and forth through these angular passage ways.

The settling influences on which the inventors depended were the growth of the particles by accretion, the loss of velocity by changes of direction and the friction and molecular attraction of the walls of the V shaped troughs. Sludge, settling out and sliding down these inclined troughs was drawn off by cocks outside the apparatus. The nearly clarified water passed through a filter occupying the entire cross-section of the upper part of the softener.

Chemical reagent tanks furnished a proportional supply of a solution of the necessary chemicals. The later machines were cylindrical and contained apron-shaped inclined shelves which were arranged around a central sludge pipe. The sludge dropping on these shelves slid down undisturbed to the point of draw-off.

These inventors added much to the art of water softening. They seem to have been the first to make lime water continuously instead of intermittently. The chief criticism which can be made of their machine is complex construction and too rapid flow of the water for the best results.

According to Delhotel, Howatson's apparatus[10] for water softening followed Gaillet's in point of time. In one form it consisted of two rectangular cone-bottom tanks, the water to

8 Delhotel: p. 329.
9 Delhotel: U. S. Pat. 563660, 1896; Pat. in France in 1893.
10 U. S. Patent 495313, 1893. Also Delhotel: p. 325.

be clarified flowing down the first and up the second. The upper half of the latter contained a series of slightly inclined partitions. Directly above these was a filter, and the purified water flowed away at the top.

These inclined partitions assisted the clarification by giving the precipitate a chance to become agglomerated into heavier flakes and to slide down the plates and settle into the cones below. The device was less perfect than Gaillet's.

Dervaux[11] and Reisert have been building softening machines in Germany for over ten years. Their apparatus has many different forms. The lime saturator however, is always "cone" or "vase" shaped, an apparent improvement, but one which later experience has shown not to be necessary. Their arrangements for feeding chemical solutions are as follows: The hard water flows into a tank at the top of the machine. On the side of this tank, near the floor and at the same level, are two openings, the flow from which is controlled by micrometer valves. One valve connects with a pipe leading to the bottom of the lime water tank, and the other allows the passage to the base of the reaction tank of the water to be softened. Saturated limewater flows from the top of the reaction tank in amount exactly proportional to the feed of hard water to the base of the tank. The stock solution of soda ash is fed to a small box in which a float valve maintains a constant level. The soda ash solution is fed through a siphon connected by a chain with a float in the hard water box.

The mixture of the chemicals with the hard water takes place either in a box near the top of the machine, as in most of the European plants or else the solutions are carried separately down and into the side of the machine as in some of the American installations. The first plan is in a general way correct. The last is bad design for only most imperfect mixing can take place without stirrers, when such a column of water overlies the point of entry.

The Reisert-Dervaux softeners have a novel feature in the submerged sand filter, which is arranged to wash itself auto-

11 Delhotel: p. 323.

matically when clogged. This is a good feature, but it has draw-backs due not only to irregular action, but to the fact that hard water replaces soft in and above the filter during washing, and the output of the machine is therefore not all softened. The resistance of sand is high, and the amount of material required to clog the filter is less than is the case with excelsior filters.

Very few successful plants of this type are in use in the United States, up to the present time.

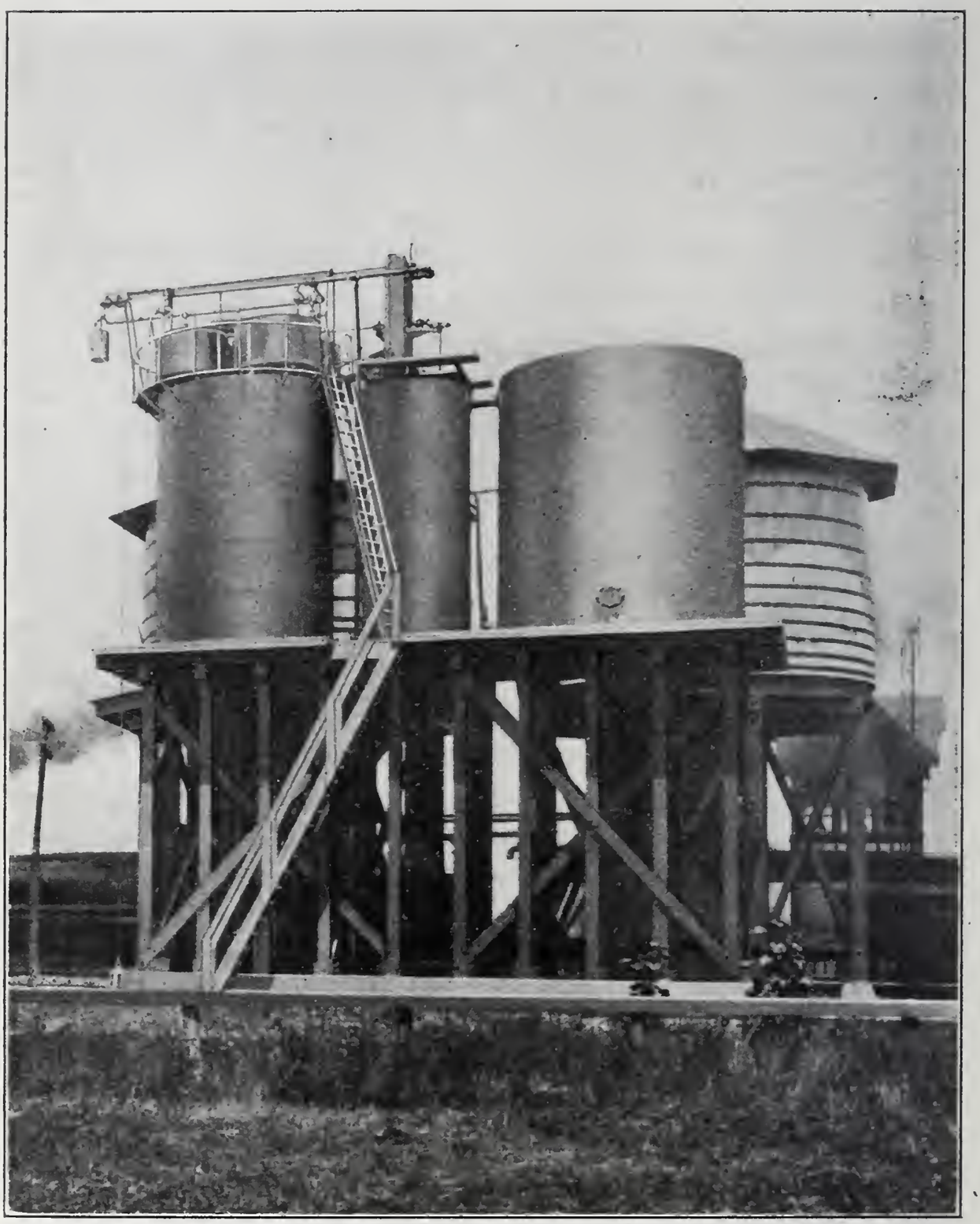
Desrumeaux,[12] a French inventor, seems to have been the first to utilize by means of a water wheel, the power of the water flowing into his softening machine. He used the power for driving a stirrer in his lime water tank. In both lime water tank and reaction tank he had annular spiral passage ways for the rising water, thus giving it a steady though circuitous upward movement, instead of, as in Gaillet's machine, a zigzag one. Sludge, settling on the spiral plates, slide to outlets properly placed to favor undisturbed fall to the cone at the base of the machine. The feed for chemicals was controlled by valves operated by floats in the hard water box.

Desrumeaux's apparatus was introduced into this country several years ago by the Industrial Water Co., of New York. The machines now being put out by this company do not contain the spiral settling device. The size of the lime water tank has been increased, and an intermediate agitating tank has been added, so that Desrumeaux's ideas, except the water-wheel, seem to have disappeared.

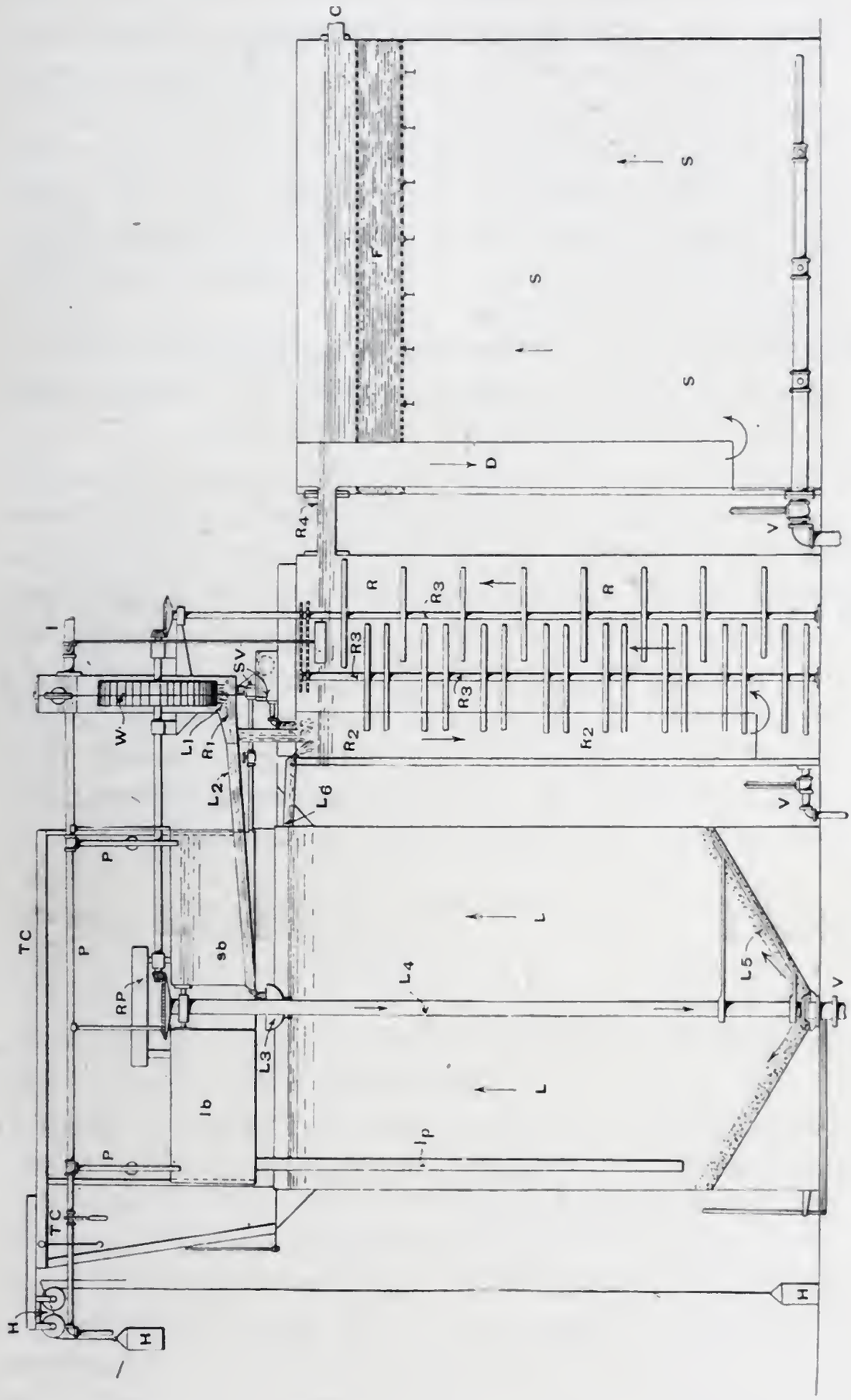
The method of operating the Industrial Machine can be seen from the cut accompaning this article. (Fig. No. 1.) This represents the arrangement at a railroad plant[13] at Middlepoint, Ohio, on the Pennsylvania Lines West of Pittsburg, North-West System.

The large lime water tank and the spiral agitating tank are the characteristic features of the Industrial plants. The designers use three comparatively shallow tanks, erected on

13 Water Softening Plant, Pennsylvania Co. R. R. Gazette, Oct. 2, 1903.
12 U. S. Pat. 513686, 1894. See also Dehotel's "L'epuration des Eaux."



WATER SOFTENING PLANT AT MIDDLEPOINT, OHIO.
Showing design of the Industrial Water Co., for railroad work. Three tank system. Lime water tank on left. Mixing tank in center. Settling tank on right.
Figure 1.



INDUSTRIAL WATER CO.'S MIDDLEPOINT, OHIO, Water Softening Plant.
L—Lime water tank. R—Reaction tank. "S"—Settling tank.
Figure 2.

trestle work, in order to deliver softened water into a railroad supply tank. This has some disadvantages, in that it requires considerable ground space, a large and quite complex foundation, and the protection of exposed pipes from freezing.

The method of hoisting lime and soda to the top of the apparatus, by filling one bucket with water until it overbalances the weight of chemicals in the other, doubtless works all right; but the disposition of the water afterward must result in waste or inconvenience.

The flat-bottomed settling tank, with perforated draw-off pipes, will require quite frequent cleaning out, because magnesian sludge will not flow well to sludge holes.

Arrangements for ensuring an even upward rise in the settling tank seem to be wanting. The filter has some steadying influence, but hardly enough to guarantee perfectly even displacement of the water in the tank by the incoming water.

Analyses made by the writer and statements made by customers indicate that the Industrial machines soften water satisfactorily in the cases which were investigated. The criticisms, therefore, pertain mainly to engineering features, which would have a bearing on the cost of attendance and maintenance, as well as uniformity of working under varied conditions.

BRUUN-LOWENER SYSTEM.

In June, 1897, U. S. Patent 583,786 was issued to Julius Bruun for a "feed water purifier" (previously patented in Denmark in 1893). The essential feature of Bruun's system is the use of a two-compartment oscillating bucket as a means of proportioning the feed of chemicals to water. The chemical solution is kept in a semi-cylindrical vessel directly over the tipping-bucket. The hard water supply flows into the bucket continuously. As soon as one compartment is filled the bucket tips and discharges, and the other compartment fills. The movement of the bucket is made to operate a stopper-valve in the bottom of the chemical supply tank. This valve is so adjusted that it allows the required amount of chemical solution to pass before it closes again, being assisted in so doing by a weight and spring. The chemicals,

cream of lime and soda ash solution, are kept in intimate mixture by means of a stirrer, which is also actuated by the motion of the tipping-bucket.

The mixture of chemicals and water flows down into the base of a cylindrical tower, and then up through an excelsior filter. The only mixing is the momentary one, occurring during the filling and emptying of the bucket, and there is no provision made to ensure steady upward rise of the water. On the contrary, the irregular feed would tend to produce eddies.

The Southampton Municipal Softening Plant, installed in 1888, was one of the first continuous softening plants of large size, and is still the largest in the world. It was a great improvement on the Porter-Clark process. It is described elsewhere in this paper. The apparently new things in water softening introduced at this plant were: (1) The use of soft water for lime water. (2) The use of cloth filters, working efficiently at low pressure.

The Municipal Softening Plant at Winnipeg is also a continuous plant and is, therefore, mentioned in this connection. Some new features found in this plant are: (1) A lime cream pump, continuously supplying lime water tanks. (2) A simple weir box and gauge. (3) Special filter presses of large capacity. (4) Efficient carbonating box of special design.

These two plants work on very different waters, which require quite different treatment.

The Kennicott Water Softening machines represent the latest developments in continuous machines, and will be described later on. Their use dates from 1900.

The oscillating bucket is not a new device in the field of chemical manufacture, but its application to water softening is suggested in Bruun's and in Gaillet's patents, the former having adopted it as an essential feature of his apparatus.

Bruun's patent claims are for use of the tipping-bucket as a means of operating a feed valve in the chemical supply tank. Subsequent users of the bucket device have caused its motion to actuate feed-pumps (Davidson), or to fill and discharge chemical solution by spoon devices. (Kennicott, U. S. Pat. 732,357.)

Archbutt and Deeley's contributions to the chemistry and mechanics of water softening may be appreciated by a study of their U. S. Patent 521,522, issued in 1894, and also an article on "The Softening of Water by the Archbutt-Deeley Process," by Leonard Archbutt, in the Engineering News, of Dec. 22, 1898, a paper read originally before the Institution of Mechanical Engineers (Great Britain).

These inventors did not believe in continuous softening machines. They preferred to work with rectangular tanks, adding the chemicals and agitating with air forced in by a steam blower, through perforated pipes lying on the bottom of the tank. They noted and laid particular stress on the influence of this sludge in hastening the softening, and also the clarification, of the water. This is one of the most important points in water softening, but it had been noticed before (Fischer, Chem. Tech. des Wassers, 1880, p. 268). The presence of crystals of carbonate of lime in suspension hastens the separation of carbonate of lime from solution by furnishing nucleii for the deposition of new crystals.

As regards the influence on speed of softening, these inventors claim that, under the most favorable conditions, four tanks, aggregating 108,000 gallons capacity, will turn out 45,000 gallons per hour. This is about twice the output which is expected from continuous plants of up-to-date design for the same tank area. The usual allowance by Archbutt and Deeley was apparently 1.4 gallons of tank capacity for each gallon of hourly output, which means for filling, agitaing, settling and drawing off, only one hour and twenty minutes.

The practice in water softening in this country is to allow four hours for sedimentation after stirring up sludge and water together. Archbutt and Deeley introduced the practice of carbonating softened water in order to remove all tendency to after-reaction. They observed that water softened by their process formed deposits in condensers, injectors, etc., and that treatment with carbonic acid in small amount wholly stopped the trouble. They burned coke and injected the combustion gases directly into the draw-off pipe. The softened water in flowing down the pipe passed over baffles, causing it to splash up into the gas and dissolve some of it.

This method of applying the gas by means of a steam blower, and apparently without washing or cooling, cannot be efficient. Experiments by the author, giving four times the length of contact under similar but even more favorable conditions, failed to effect complete carbonating. It was necessary to change the method of exposure entirely.

In 1896, Goldsmith took out U. S. Patent 558,018, and started to build water softening plants, operating under what he called the We Fu Go System. This system differs in no essentials from Archbutt and Deeley's plan, except that a steam engine is used to drive a paddle for agitating the water with the chemicals, instead of a steam blower injecting air for the same purpose. Neither device is original or patentable. The claims in Goldsmith's patent are for combinations of devices for feeding chemicals, and for stirring and drawing off the softened water. These methods were not adhered to in his later practice, nor were patentable devices substituted therefor. The softened water is filtered through a sand filter, embodying no features especially different from the usual gravity filter.

The results obtained by the use of We Fu Go Plants have been excellent, so far as we know. The conditions for proper softening are very perfectly fulfilled. If the treatment is based on a correct chemical analysis, it is sure to be successful.

The system may be justly criticised on the following grounds:

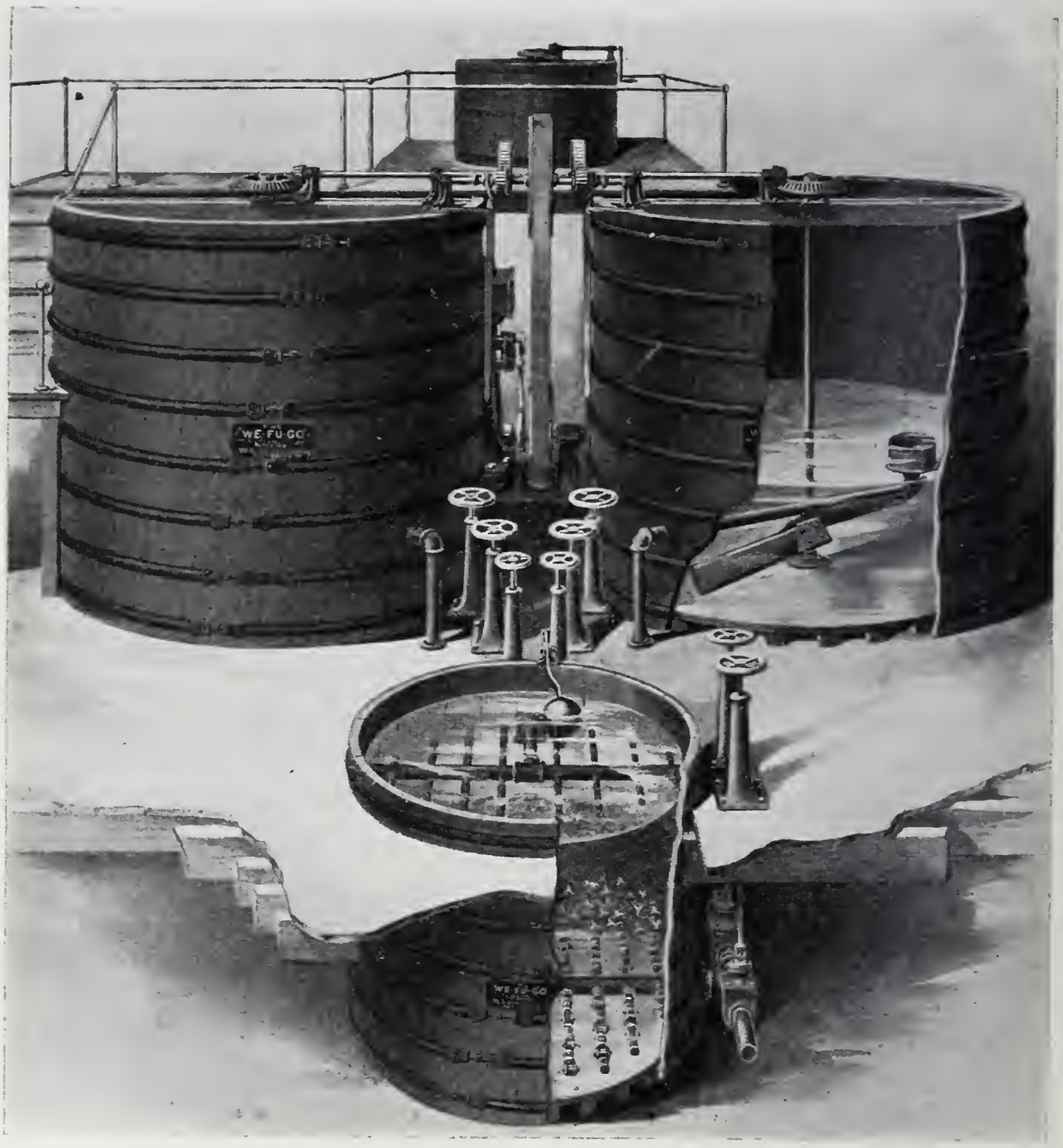
(1) The system is intermittent. The feed and draw-off must be changed alternately from one tank to the other. Numerous valves have to be opened and closed.

(2) Frequent weighing out of chemicals and preparation of solutions is necessary.

(3) The tanks occupy much floor space.

(4) Unless raised on trestle work to give a gravity supply, all the water has to be pumped twice. Even if the total lift were no greater in the latter case, it would be a drawback, and an extra expense.

(5) Outside power is required for running paddles in treating tank, rakes in filter tanks and the hoist for lifting the chemicals.



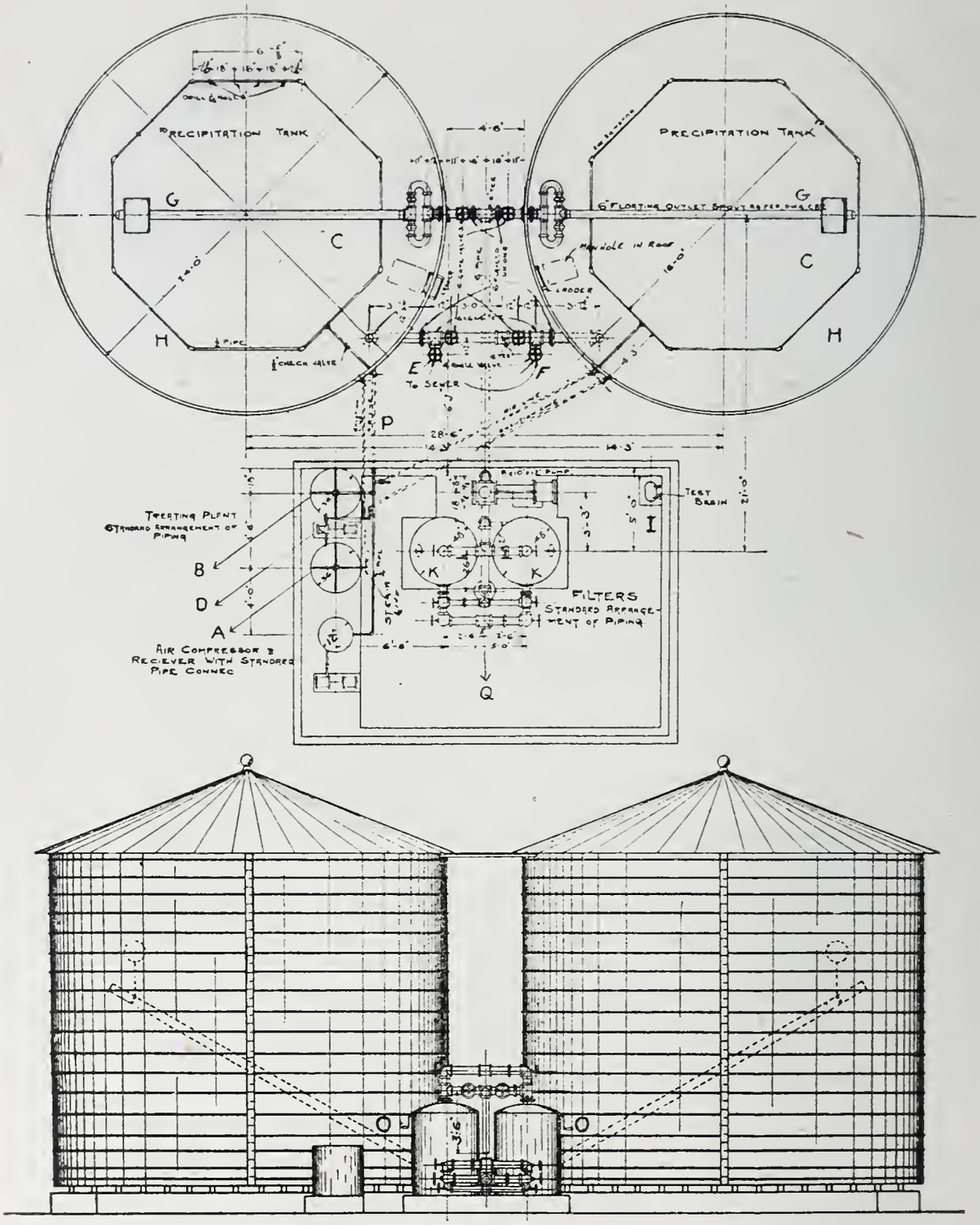
WE FU CO. PLANT FOR SOFTENING WATER.
General arrangement of tanks, filter, valves, etc.
Figure 3.

The "Ideal" system of water softening, used by the Pittsburgh Filter Mfg. Co., is in most respects similar to the Archbutt-Deeley process. It is intermittent. Air is used for agitation but it is furnished by a small pump instead of a steam blower. The chemical solutions are prepared at ground level and pumped to the treating tanks, thus saving the necessity for a hoist, and making it unnecessary for the attendent to go frequently up on the tanks. As in the We Fu Go system, sand filters complete the clarification of the water. These are of gravity or pressure type, as occasion may require.

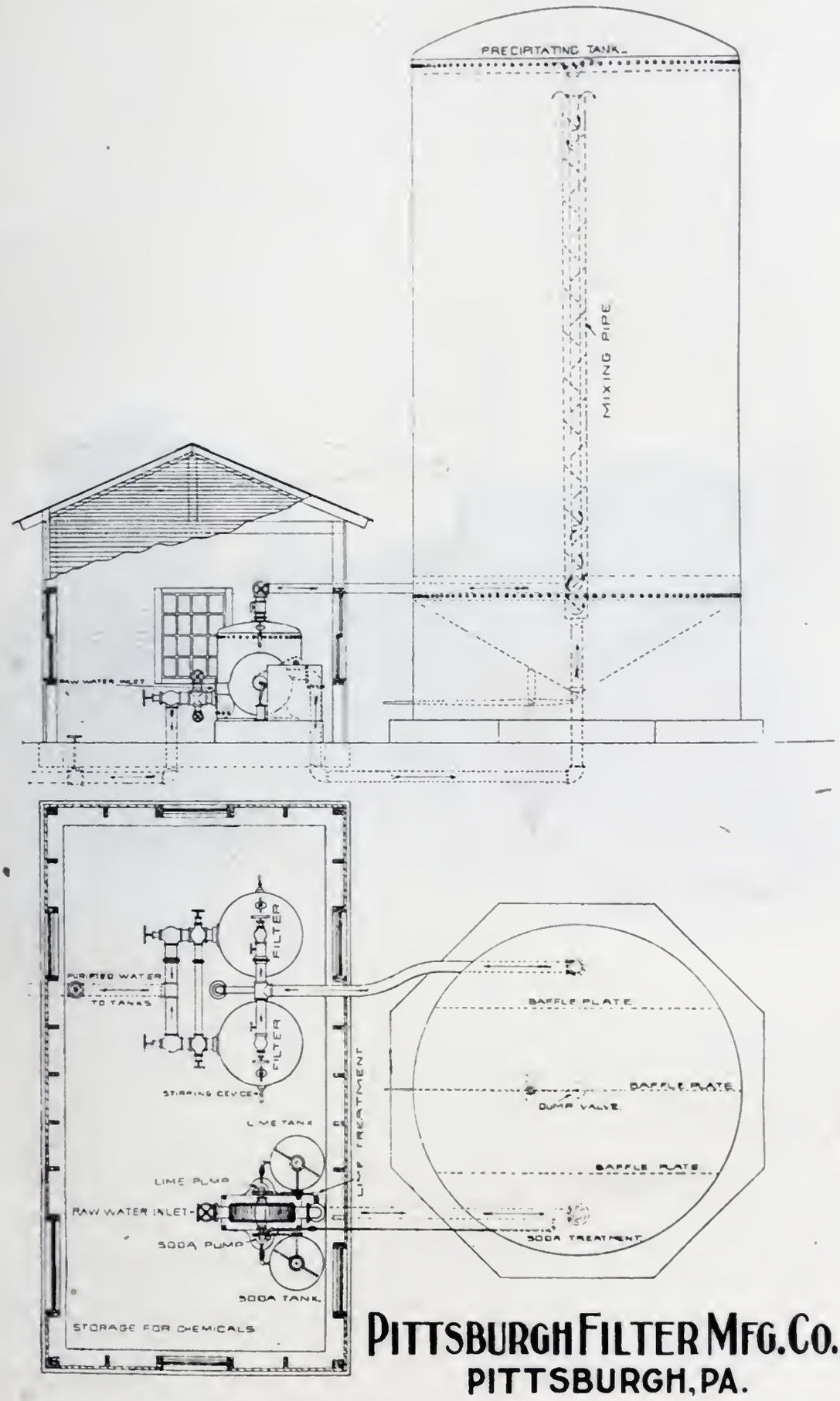
Both of the companies just mentioned make plants especially for treating hot water, the chemical solution being pumped into the feed line, and then passing successively through a mixing tank and a sand filter into the boiler. Filters are in duplicate, so that one can be cut out for cleaning when necessary. In neither case is the general plan original. The Solvay Process Co., at Syracuse, N. Y., have purified and filtered their boiler water in essentially the same way for many years.

Stillman has taken out patents 595,793 (1897) and 656,331 (1900). These devices are for use in connection with railway water stations, and have been tried on the Southern Pacific Railway. The novelties in Stillman's plan consist in the use of compressed air for running a mechanical stirrer in his chemical tank, and also for forcing the solution into the water main. After entering the main, the mixture is made to flow through circulating tanks containing baffles. Thence it passes into the railroad service tank, which is used as a settling reservoir. The water then has to be drawn off through floating discharge pipes, and the sludge through appropriate drains.

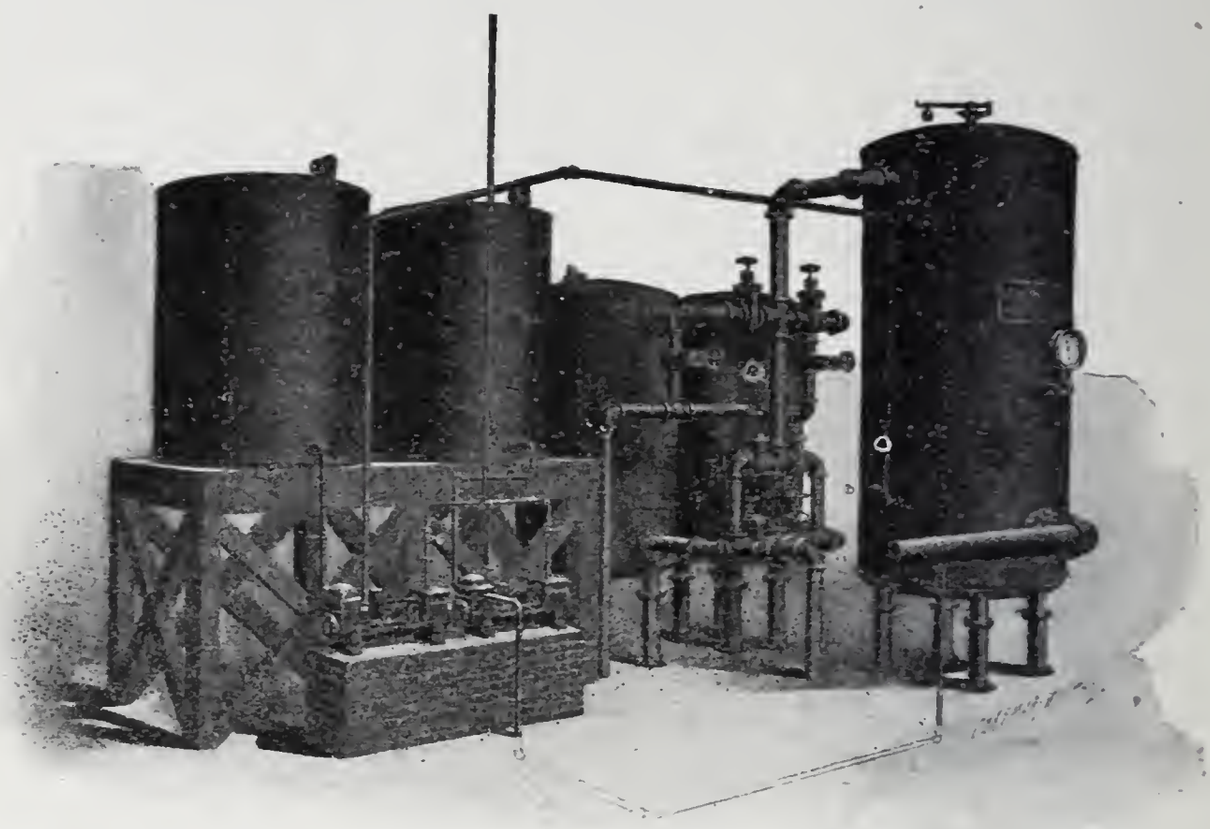
In the later patent, a water motor takes the place of the air-motor. In criticising Stillman's method it may be said that it is an advance over the old method of sucking the chemical feed in through the service pump, in that it provides means for keeping the chemical solution stirred, and for mixing it afterward more perfectly with the water. The use of the railroad tank as a part of the softening apparatus seems to us poor economy, except as a temporary makeshift. The removal of sludge from



Water Softening Plant.
"Ideal" (Intermittent) system. Pitts. Filter Mf'g. Co.
Figure 4.



WATER SOFTENING PLANT; CONTINUOUS TYPE.
Chemicals fed by pumps actuated by water motor.
Figure 5.



SCAIFE PLANT FOR SOFTENING HOT WATER.
Chemical tanks and feed pumps on left. Mixing tanks on the right.
Filters in center.
Figure 6.

a flatbottomed tank must of necessity be unsatisfactory. The passage of water and chemical solution through a chamber with baffles is old in water softening practice.

Compressed air for regulating chemical feed was first used in the Porter-Clark process.[14] Later on the same people used a water motor for actuating chemical feed pumps.[15]

Published analyses (Railway Age, June 21, 1899, page 13), show that Stillman obtained satisfactory results. While possibly cheaper to install, the method, as a whole, cannot be recommended.

G. M. Davidson (U. S. patents 712,770, 712,771, 715,031 and 729,121, taken out in 1902 and 1903) has devised a method of water softening which is in use at several points on the C. & N. W. Ry. He feeds his chemicals proportionately and continuously into the water by means of an adaptation of the tipping-bucket device. As the bucket tips back and forth it operates a stirrer in the chemical supply tank, and at the same time actuates two feed pumps which deliver the chemical solution in fixed proportions into the bucket.

The use of a tipping-bucket is not new, but the pump attachment is believed to be so. The Bruun-Lowener softener,[16] used in Denmark and to some extent in this country, has a tipping-bucket, the chemical solution being fed in from an overhead supply, through a stopper valve raised by a cam each time the bucket tips, and seated again by a spring.

Davidson, after filling a tank with water to which the proper amounts of chemicals have been added, agitates further by pumping water from the upper part of the tank and forcing it in at the bottom through a perforated pipe lying in the sludge. By this means a thorough contact with sludge with its attendent benefits is obained. The time allowed for filling, settling and emptying is twelve hours. The standard plan has two 30′ tanks 16′ high. These deliver, if necessary, 240,000 gallons in 24 hours. The tank capacity is about 154,000-gallon tons for an hourly output of 10,000 gallons.

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14 Desrumeaux:
15 Rideal: "Water and Its Purification," 1897, p. 219.
16 U. S. Pat. 583786, June, 1897, Feed Water Purifier, Julius Bruun.

In criticising the Davidson plant it may be said:

(1) That the appliances are well suited for perfect softening of the water. Results are chemically satisfactory and good results are obtained from the use of the water in locomotive boilers.

(2) The plant is the simplest and probably is less expensive to install than some of the machines on the market.

(3) In the matter of operation, however, the arrangement for drawing off the excess sludge seems imperfect. Magnesian sludge clings persistently to flat-bottomed tanks.

(4) The output for a given tank area is very low indeed.

(5) The ground space and housing required are very considerable.

For further particulars see "The C. & N. W. Ry. Co.'s Method of Purifying Water for Locomotive Boilers," G. M. Davidson, Proceedings of Western Railway Club, Feb. 17, 1903. See, also, Railway & Engineering Review, Oct. 31, 1903, p. 783, for statement of cost of operating Davidson plants in July. The figures vary from 0.73 to 6 cents per 1,000 gallons, interest and depreciation not included.

THE KENNICOTT SYSTEM OF CONTINUOUS WATER SOFTENING.

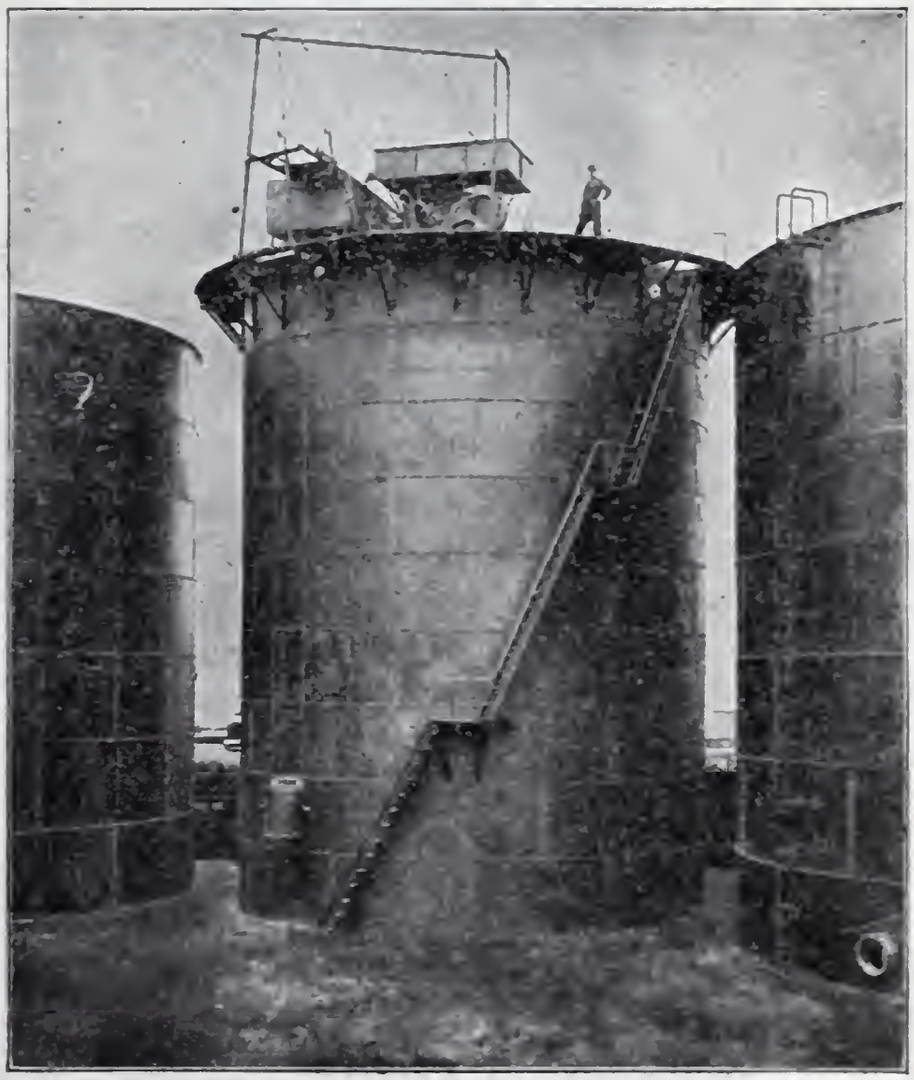
U. S. patents 646,108, 665,606, 703,596, 708,717, 717,215, and 732,357. March 27, 1900, to June 30 ,1903.

This system is very extensively used in the United States, particularly in the railroad field. It is, however, of general application. Railroad requirements are more severe than any, except possibly municipal.

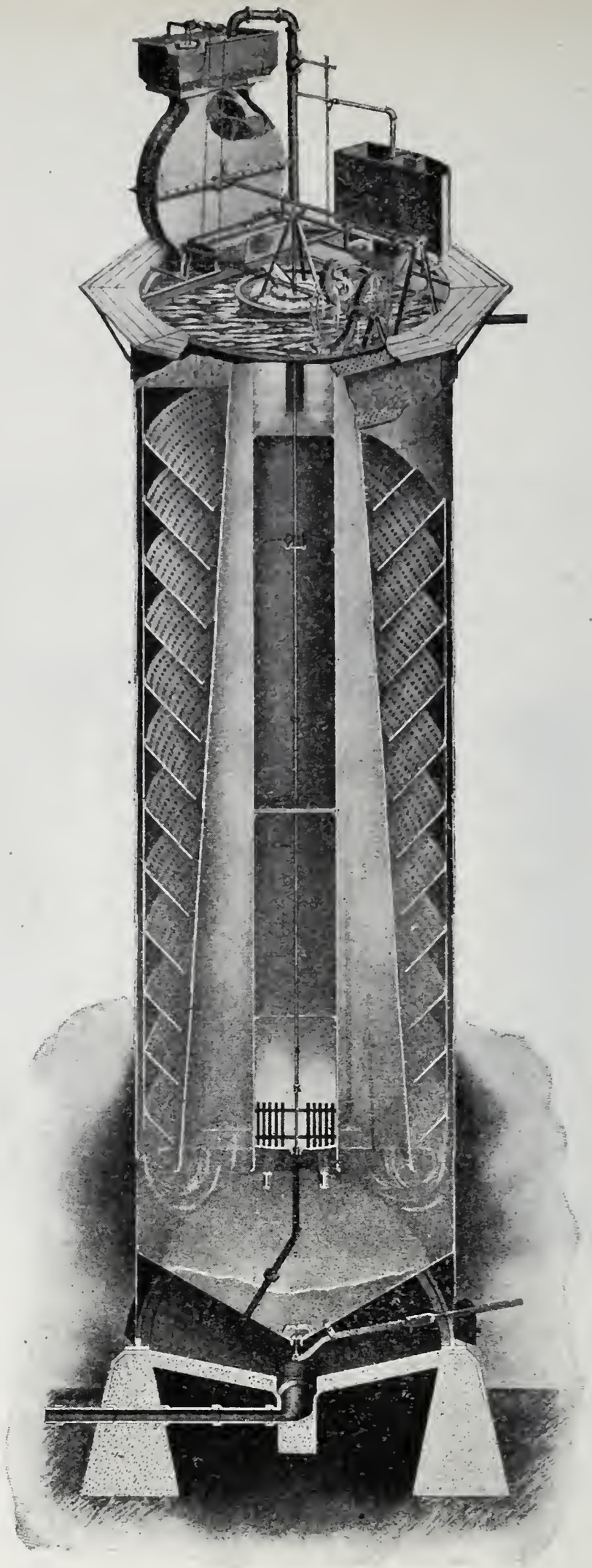
Fig. 7 shows a 60,000-gallon per hour plant installed for the P. & L. E. R. R. Co., at McKees Rocks, Pa. Fig. 8 shows a sectional view of a Kennicott machine.

The general plan of working is very simple, indeed, the feed of chemicals and all the necessary stirring being automatic. The turning on of the water starts everything in operation and shutting it off stops it.

The hard water enters a box near the top of the apparatus and flows out through a slot in the bottom to a water wheel.



Kennicott Water Softener, McKees Rocks, Pa.
Capacity 1,440,000 gallons. P. & L. E. R. R. Co. plant.
Softener in center. P. & L. E. storage tanks at side.
Figure 7.



KENNICOTT WATER SOFTENER.
Cut shows water-wheel, chemical feed device, mixing cylinder, settling cone, baffle-plates, enclosed lime water tank, etc. Hard water enters at top. Soft water flows away at top.
Figure 8.

(The slot is made of the proper size to discharge the maximum quantity of water which is to be treated.) The water wheel operates a stirrer in the lime water tank, and also a lift wheel for raising soft water to the lime water measuring box. It has been found economical to use soft water for making lime water, and by means of this lift-wheel soft water is raised with very little power, indeed, to the point of use.

Soda ash, enough for 6, 12 or 24 hours, is dissolved in a tank, and is fed by a pipe controlled by a ball-float valve to a measuring box on a level with the lime water feed box. A float in the hard water box is connected by chains with swivel-joint lift pipes in the feed boxes.

As the level of the water over the slot in the hard water box rises and falls the lift pipes, which have openings in their upper ends proportional to the size of the slot in the hard water box, rise and fall, also. The length of each chain is so adjusted that the head of water over all three slots is always the same. The sizes of the slots in the lift pipes are made adjustable by screw caps. It is thus a simple matter to change the proportions of chemicals to hard water at any time.

The soft water delivered to the lime water feed box passes through the slotted lift pipe, which connects with a pipe passing to the bottom of the central lime water tank. Here it passes up through the excess of lime cream, and is changed into saturated lime water, which, flowing upward, meets the mixture of hard water and soda solution which have come together at the point of discharge below the water wheel.

A very thorough stirring takes place at this point, and the mixture flows upward and passes over the rim of the mixing cylinder. It then starts down the annular conical space outside the lime water tank. In this cone the velocity of the water constantly decreases and the sediment produced by softening the water gradually settles away from the descending current. Arriving at a point just above the sludge cone, the water turns upward again, passing through baffle plates and depositing nearly all of the rest of the suspended matter. It finally flows through a wood-fiber filter and passes over into the service tank.

These machines are so designed that they deliver water into elevated service tanks without repumping. They require only one foundation, and the parts are well protected from freezing.

Tests by the writer prove that the conditions favoring uniform and complete softening are well taken care of in the Kennicott machine. The degree of softening is as high as with any machine, and the results are uniform when reasonable care is given. The amount of labor actually necessary for operation is less than with any other machine with which we are familiar.

In criticism of the Kennicott machine it may be said that the feed of lime water is discontinued when sludge is blown out. The water level above the filter falls slightly and the lift wheel cannot reach soft water until it rises again. This defect, which has apparently not interfered with general success, will doubtless be remedied. (NOTE: New device remedies trouble.)

The novel and valuable features of the Kennicott machines are: (1) The proportional feeding device for chemicals. The slotted lift pipes are simple and easily adjustable. (2) The mixing arrangements *inside the main tank*. The Industrial mixer is a separate tank. (3) The conical down-take pipe, giving a descending water column of decreasing velocity, out of which the precipitate settles easily. Other machines have only a narrow cylindrical down-take pipe, or none at all. The base of the down-take cone is made of such area that there is no sudden increase of velocity when the current turns up again, but only a steady increase in the size of the passage all the way to the top. (4) The baffle plates not only steady the upward rise but assist in the final clarification and completion of softening in a way not always appreciated.

SUMMARY.

The essential principles of water softening which any successful machine must meet, are as follows:

(1) The scheme for feeding chemicals in the *continuous* system must be very precise at all times, and capable of easy adjustment when necessary. The devices must be as simple as is consistent with precision.

(2) The chemicals and water must be very thoroughly mixed, and for a sufficient length of time under proper conditions, so that the softening is sure to be completed in the time allowed.

(3) In the case of a *continuous* softening machine, its internal construction should be such that the steady progress of water through the machine is certain. There must be no eddies. If the supply is delivered intermittently or the rate of pumping is variable, it is absolutely essential that the uneven flow be counteracted. There is a tendency toward short cuts in any case which the apparatus should be designed to meet.

(4) The apparatus should be so designed that clarification will be very complete, leaving an insignificant amount of work for the filters. This reduces the trouble and expense of operation.

(5) The time allowed for the completion of the chemical reaction must be sufficient. The apparatus, if *continuous* in operation, should hold four times the maximum hourly output required. If *intermittent,* the time for filling and emptying tanks must be added to the four hours standing. This makes the tank area in the *intermittent* system usually about twice that in the *continuous* system.

(6) The softened water should be perfectly clarified when discharged.

(7) Labor and superintendence must be cut down to a minimum.

Judged by such of these standards as apply to *intermittent* systems, the We Fu Go, Ideal, Stillman, and Davidson systems are properly designed to secure satisfactory softened water. They vary from each other in the amount of labor required to operate, the Davidson being apparently the simplest of the intermittent plants.

All *intermittent* plants except possibly the Archbutt and Deeley[17], require from two to four times as much tank capacity as the *continuous* machines for the same output.

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17 Archbutt and Deeley by drawing off without filtration in an hour or less, make carbonating necessary and materially limit the degree of softening.

(6) *Chemical Regulation.*—The work of the intermittent plants when not located at places having a chemist is only checked up by imperfect chemical tests, (red color with phenolphtalein, and color with silver nitrate).

Parties installing continuous plants, train operative to make simple but more enlightening tests (hardness, alkalinity, etc.).

SUMMARY.

Continuous and *intermittent* softening plants properly designed and conscientiously cared for, give first-class results. In order to get these results by the *intermittent* system it requires a larger plant, more labor and more power. Intelligent supervision is required for both kinds of softeners.

The *continuous* system has the advantages of simplicity and compactness, and is cheaper to operate, because it requires less power and less labor. The maintenance charges are less, if, as is usual, steel construction is used. Having few valves (one-fourth as many as is in the intermittent system), there is little to get out of order.

EXTENT OF WATER SOFTENING OPERATIONS AND BENEFITS DERIVED.

There are in the United States and Canada to-day, about 275 water softening plants, with an aggregate capacity of approximately 65,000,000 gallons per day. Of these plants over 100 are in railroad service. The rest are distributed as follows:

Iron or steel works	35	plants.
Ice factories	16	"
Electric lighting companies	6	"
Street railways	4	"
Paper manufacturers	9	"
Laundries	6	"
Woolen mills	2	"
Glass companies	2	"
Cement manufacturers	3	"

Other users include:

Gas works,	Powder works,
Water works,	Coal mining companies,
Municipalities,	Sugar refineries,
Hospitals,	Breweries,
Hotels,	Smelting works.

lons. Hourly output = *one-fourth* of tank content. Ground space =*830* sq. ft.

It will be noted that while the first plant mentioned above occupied about four times the area used by the other, and had twice the tank capacity on the same basis, yet its output was just half. The ratios of tank capacity to hourly output of several plants are:

Clark process (original *intermittent*) 29:1
We Fu Go (modern *intermittent*) 8:1
Kennicott (modern *continuous*) 4:1

The output of the Kennicott plant is seven times that of the Clark system, and twice that of the We Fu Go per unit of tank capacity.

(3) *Labor in Operation.*—1,200,000-gallon We Fu Go Plant, Lorain, Ohio.—Man required to run engine and look after shafting, belting, etc.: 24 large valves to be opened and closed daily at proper time. Two filters to clean. Sludge excess to be removed from four tanks. Twelve batches of chemicals to be weighed out.

The 1,440,000-gallon Kennicott Plant, McKees Rocks, Pa.—Boy to weigh out and prepare batch of chemicals every six hours. No engine or shafting. One valve opened to remove sludge four times a day. Dumping sludge lowers water and cleans filter.

(4) *Power for Operation.*—We Fu Go Lorain Plant.—Engine required to run stirrers in four 30′ tanks and rakes in two 16′ filters. Plant *depends on steam power* to keep running.

Kennicott, McKees Rocks Plant.—All stirring or lifting required is done by the power of the water falling eight feet. The power required is very small, as only one narrow blade stirrer is used. The use of the water for power makes the plant *independent*. When water is pumped to the plant everything starts.

(5) *Durability and Maintenance.*—In most cases the intermittent plants are of wooden construction while the continuous ones are of steel. The depreciation of steel tanks will be next to nothing, because the alkaline solutions have a protective influence. This is not true of wood.

The Industrial and the Kennicott machines are the only two *continuous* types which can be approved of when critically examined, and the measure of approval is less in the former than in the latter case, for reasons already enumerated.

INTERMITTENT VS. CONTINUOUS.

WATER SOFTENING PLANTS.

(1) *Character of Work Done.*—Comparing results on waters of similar character we find good work by both types.

	No. 1.		No. 2.		No. 3.	
	Lime.	Magnesia.	Lime.	Magnesia.	Lime.	Magnesia.
Hard Water... ...	9.80	5.62	7.40	2.46	23.75	4.60
Softened Water...	0.55	2.39	1.85	1,23	1.69	3.80
	No. 4.		No. 5.		No. 6.	
	Lime.	Magnesia.	Lime.	Magnesia.	Lime.	Magnesia.
Hard Water... ...	19.46	6.60	27.8	8.54	24.04	10.10
Softened Water...	1.42	1.22	2.17	0.72	2.56	.88

Results show parts per 100,000.

Nos. 1 and 4 are Kennicott plants (*continuous*).

Nos. 2 and 3 are Pittsburg Filter Mfg. Co. plants (*intermittent*).

Nos. 5 and 6 are, respectively, Davidson and Stillman plants (*intermittent*).

The fairest test of the work of a softening plant is not the original hardness of the water, but the amount of lime and magnesia left in the water. Water of only moderate hardness is often more difficult to treat than a very hard one.

The lime is reduced to a smaller figure by the Kennicott plants, while the magnesia is brought a little lower by some of the others.

All of the results are good. The author made analyses 1, 2, and 3. The chemist of the Union Pacific Ry. made No. 4, and No. 5 and No. 6 were by Mr. G. S. Davidson. (The original figures were stated in grains of calcium carbonate, etc.)

(2) *Comparative Output of Plants.*—We Fu Go (*intermittent*); Lorain plant.—Four 100,000-gallon tanks = 400,000 gallons, produce 50,000 gallons per hour. Hourly output = *one eighth* of tank capacity. Ground space for plant = *3230* sq. ft.

Kennicott (*continuous*), McKees Rocks.—Capacity of softener = 257,000 gallons (gross). Hourly output = 60,000 gal-

The extent to which water softening has already been carried in this country is in itself convincing proof that it *pays well*. Further proof may be found in a few concrete cases:

(1) The Chicago, Milwaukee & St. Paul Ry., by the use of soda ash, saved $75,000.00 per annum on boiler repairs.

(2) The Union Pacific Ry. Co., by the use of tri-sodium phosphate on one division for six months, obtained the following results: (*a*) Increased engine mileage 42.5%. (*b*) Washing out, decreased 60%. (*c*) Boiler work, decreased 63%. (*d*) Flues in better condition than ever before. The expense of treatment was too great and machines using lime and soda ash have replaced the phosphate plan.

(3) The Nichols Chemical Co. of New York, by the use of a continuous water softening machine obtained the following benefits: (*a*) Fuel saving of 20%. (*b*) Labor saving of 25%. (*c*) Boiler repair saving of 75%. For a 2,500 H.P. plant, labor and chemicals cost only $2.40 per day. The water is no harder than Monongahela river water, before treatment.

(4) The Consumer's Co., Chicago, ice manufacturers, (Mr. J. T. Cole, Manager), installed a water softening machine and estimate the benefits derived as follows, on the basis of the same output:

Annual coal bill *before softening water*, 22,000 tons, at $1.35	$29,700 00	
Cost of removing scale from boilers	780 00	
		$30,480 00
Annual coal bill *when softening water*, 18,333 tons, at $1.35	$24,749 55	
Cost of removing scale	0 00	
Chemicals for softening	255 00	
Six per cent. interest on cost of plant	294 00	
		$25,298 55
Saving due to softening		$ 5,181 45

This exceeded the first cost of the plant, which, therefore, paid for itself in a year. The water used was from Lake Michigan, and is not harder than Monongahela river water.

ANALYSES OF TYPICAL WATERS.

Parts per 100,000.

Nos. 1- 3. Good waters, giving no trouble in boilers.

Nos. 4- 7. Fair waters, which, however, it pays to soften.

Nos. 8- 9. Poor waters, the use of which, in locomotives boilers, makes new fire boxes necessary in two years.

Nos. 10-11. Waters which foam in locomotive boilers.

	1	2	3	4	5	6	7	8	9	10	11
Silica	0.24	1.55	.83	0.60	.....	.56	.....	2.45	2.99	.....	.....
Carbonate of Lime	0.89	1.92	2.52	6.90	6.16	2.68	.....	42.05	23.20	5.27	2.59
Carbonate of Magnesia	0.14	1.90	.92	3.23	1.73	.46	.....	2.03	12.17	.46	1.64
Sulphate of Lime	2.19	1.30	.39	.58	.....	3.40	11.66	10.72	.....	1.19	.....
Sulphate of Magnesia	.....	.....	.....	.85	.....	.45	4.83	22.98	.....	.....	.....
Chloride of Lime	.20	.....	.....	.....	.....	.....	.....	.....	.....	12.29	.....
Chloride of Magnesia	.58	.....	.....	.....	2.19	1.25	.....	.....	.....	5.19	.....
Chloride of Soda	.....	.07	.80	.....	1.52	2.47	1.82	2.86	.15	30.18	5.86
Sulphate of Soda	.....	.94	.....	.....	5.84	.....	1.03	9.62	1.15	.....	22.74
Free Sulphuric Acid	.....	.....	.....	.....	.....	.....	0.98	.....	.....	.....	.....
Sodium Nitrate	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.15

No. 1. Youghiogheny river water from point above Connellsville.

No. 2. Grand Rapids, Wisconsin, well water analyzed by G. M. Davidson.

No. 3. Wellington, Mich., same analyst as No. 2.

No. 4. Lake Michigan water, Chicago, Ill.

No. 5. Nichols Chemical Co.'s supply, Long Island.

No. 6. Allegheny river water, furnished to Pittsburgh, October 8, 1903.

No. 7. Monongahela river water at Rankin, Sept. 9, 1903.

No. 8. Well at Council Bluffs, Iowa, G. M. Davidson, analyst.

No. 9. Well at Boone, Iowa; ibid.

No. 10. Water supply at Beaver Falls, Sept. 29, 1900. Caused foaming when concentrated.

No. 11. Softened water. Foams when concentrated about 8:1.

PART III.

The Chemistry of Water Softening.

Before taking up the question of water softening, it is necessary to have a correct analysis of the water which it is desired to improve.

A prominent superintendent of motive power of a well known railroad, recently told us that of six chemists working on parts of same sample of water, only three agreed within reasonable limits. We presume that the differences arose chiefly from methods of combining the acid and basic radicals found.

In June, 1899, we analyzed waters from the Chicago & Alton Ry. Co.'s wells at Bloomington and Joliet, Ill., and give for comparison, the results turned in by another chemist on the same waters.

Parts per 100,000.

	Bloomington.		Joliet.	
	P. T. L.	H-t.	P. T. L.	H-t.
Carbonate of lime	29.15	3.66	28.29	3.30
Carbonate of magnesia	3.47	16.32	3.44	24.96
Sulphate of lime	1.65	19.75	7.58	42.70
Sulphate of magnesia	16.36	.....	34.71	.....
Sulphate of soda	.....	.....	1.12	.....
Chloride of soda	3.14	2.93	14.85	13.99
Carbonate of soda	1.97	5.60	1.06	6.73

The samples were not taken at exactly the same time, but evidently we were working on substantially the same waters. The salt determinations indicate that. Otherwise we differed widely. We based *our* allotment of acids to bases on the behavior of the constitutents after evaporation to dryness. Lime which remained insoluble in hot water certainly was not present as sulphate, chloride, or nitrate.

As the magnesia, after evaporation to dryness, went mainly into solution in hot water, it could not have been present in the water as carbonate.

There is a theory that all the sulphuric anhydride found in water should be combined with lime if enough is present, and if not, give it all it will take. The other chemist seems to have worked on that plan.

This theory is advanced by Leffman. ("Examination of Water," p. 112.) He says: "Since it is known that, at the high temperatures ordinarily reached in boilers, definite chemical changes occur, it is safest to exhibit the maximum amount of corrosive and scale forming ingredients which the water, under these circumstances could develop. Thus as calcium sulphate is practically insoluble in water above 212° F. (?), the proportion of calcium sulphate may be regarded as such as would be formed by the total quantity of calcium or the total quantity of sulphuric acid, according to which is present in the larger amount. Similarly, as the decomposition of magnesium chloride is induced by the high temperature of the boiler, the analytic statement should indicate the maximum proportion of this compound obtainable from the magnesium and chlorine present. These rules cannot apply absolutely to waters rich in alkali carbonates, since these would neutralize any acid formed from magnesium chloride, or even prevent its formation, and would prevent to a large extent the formation of calcium sulphate. Much remains to be determined concerning the effects of high temperature and concentration to which boiler waters are subjected."

This was in 1895. We do not know whether Mr. Leffman holds to the same views now concerning the best method of expressing results of analysis. Certainly no accurate calculation for water softening purposes could be based on results expressed by his method.

On the basis of our analyses, we figure lime and magnesia compounds in Winnipeg water as shown in the first column.

	Parts per 100,000.	
	P. T. L.	U. of M.
Carbonate of lime	20.29	7.0
Carbonate of magnesia	11.30	23.7
Sulphate of lime	0.60	21.6
Sulphate of magnesia	17.25	....

A chemist at the University of Manitoba insists, however, on figuring it as shown in the second column, in spite of the fact that almost all of the lime comes down as insoluble carbonate on evaporating to dryness.

These instances will serve to illustrate the need of thorough discussion, and agreement on a uniform method of obtaining and expressing the analytical results on which water softening calculations are based.

METHOD OF ANALYSIS.

Our method of analysis, which has already been hinted at, is in outline, as follows:

Evaporation to dryness on the water bath. Treatment with the boiling distilled water free from carbon-di-oxide. Filtration and washing with boiling water. The residue is thoroughly rubbed up with a rubber-coated rod. If the water is high in sulphates, use plenty of hot water.

Dissolve the insoluble part in dilute hydrochloric acid. Determine iron, lime, and magnesia volumetrically in both soluble and insoluble portions. Express results as soluble and insoluble lime and magnesia. Determine silica in separate portion.

Determine chlorine and sulphuric anhydride by usual methods.

Determine alkalinity or acidity by adding a measured excess of standard d.n. sulphuric acid to 100 c.c. of water, boiling 20 minutes in platinum or porcelain, and titrating back with decinormal sodium hydrate, using phenolphtalein indicator. Calculate acidity to sulphuric acid or alkalinity to calcium carbonate.

Determine nitric anhydride by the phenol-sulphuric method, using silver sulphate to remove chlorine before evaporation, and adding a little sodium carbonate to prevent loss in evaporation.

Free Carbon-Di-oxide is determined if the sample has been sent in a sealed condition, so that the gas has not escaped. This is determined by titrating 50 c.c. in a nessler tube, with 1/50 N. sodium carbonate. (Seyler's Method.)*

CALCULATION.

Our calculation of chemical treatment required for softening hard water or neutralization of acid water is based entirely on the amounts of free carbon-di-oxide, soluble and insoluble lime and magnesia, free acid and iron.

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*"Estimation of Carbon Di-oxide in Water," Ellms and Benneker, Jour. Am. Chem. Soc., 1901, p. 405.

About these there can be no discrepancy if our method of separating soluble and insoluble lime is followed and the analyses are accurate.

It is in the less important matter of arbitrarily disposing the acids among the bases that chemists differ. Our own practice is to calculate insoluble lime and magnesia to carbonates. The residual alkalinity is figured to sodium carbonate. There can be no argument about this. When, however, we have to decide how much of the soluble lime is combined with sulphuric anhydride or other acids, and the same for the soluble magnesia, we realize that we can longer proceed logically, but must follow an arbitrary practice.

It is possible by using dilute alcohol for extraction of the original solid residue to leave calcium sulphate behind with the carbonates of lime and magnesia. This, however, seems to us of questionable advantage, as the separation of all sulphate of soda is difficult, and sulphuric acid has to be determined twice. We have not used this method, but if we undertook it we think that it would be best to make the separation by water first, then evaporate to dryness, and extract with alcohol.

Our arbitrary method of calculating is to give the soluble lime first sulphuric anhydride, then chlorine, then nitric anhydride until satisfied. Satisfy soluble magnesia in the same way with what remains, calculate residual acid radicals to soda, unless both soda and potash have been determined. In that case satisfy soda first.

The question is whether to recommend the introduction of the alcohol method into *ordinary practice* for the sake of actually determining sulphate of lime, or to figure all soluble lime to sulphate, if there is enough sulphuric acid present.

It may be supposed that calcium chloride and nitrate, and the corresponding salts of magnesia, including also the sulphate, do not form scale, and, therefore, need not be removed. In reply to this it may be said that it is doubtful whether any magnesium salts are stable under boiler conditions, and they should all be removed to prevent corrosion. It is difficult, if not impossible, to partially treat a water so as to leave calcium chloride and nitrate

undisturbed. They are objectionable, as they change to sulphate if magnesium sulphate is present. They should, therefore, be removed.

The chemical equations involved in water softening are familiar to you all, but will, perhaps, bear repetition, as the necessity for certain points is often overlooked.

PURIFICATION BY LIME AND SODA.

The Chemistry of the Process.

Bicarbonate of lime requires one equivalent of slaked lime for its removal.

$$CaCO_3CO_2+CaH_2O_2=2CaCO_3+H_2O.$$

Bicarbonate of magnesia requires two equivalents of lime. The first liberates magnesium carbonate, and the second changes the somewhat soluble carbonate to hydrate, which is quite insoluble.

$$MgCO_3CO_2+2CaH_2O_2=2CaCO_3+MgH_2O_2+H_2O$$

Carbonic acid requires one equivalent of lime.

$$CO_2+CaH_2O_2=CaCO_3+H_2O$$

Free sulphuric acid, or sulphate of iron, requires one equivalent of lime and one equivalent of soda.

$$H_2SO_4+Na_2CO_3+CaH_2O_2=Na_2SO_4+CaCO_3+2H_2O$$
$$FeSO_4+Na_2CO_3+CaH_2O_2=Na_2SO_4+CaCO_3+FeH_2O_2$$

Soluble lime salts while not all scale-formers, are best removed when softening water. They require one equivalent of soda.

$$\left.\begin{matrix}CaSO_4\\CaCl_2\\CaN_2O_6\end{matrix}\right\}+Na_2CO_3=\left\}\begin{matrix}Na_2SO_4\\2NaCl\\2NaNO_3\end{matrix}\right\}+CaCO_3$$

Soluble magnesia salts require one equivalent of lime and one of soda.

$$\left.\begin{matrix}MgSO_4\\MgCl_2\\MgN_2O_6\end{matrix}\right\}+Na_2CO_3+CaH_2O_2=\left\}\begin{matrix}Na_2SO_4\\2NaCl\\2NaNO_3\end{matrix}\right\}+CaCO_3+MgH_2O_2$$

In calculating cost of water treatment, it is customary to figure to pounds of each chemical required for 1,000 U. S. gallons.

In the following table, I base my estimates on 90% lime and 95% soda ash; because, while you may buy the best grades of these materials, you are apt to get shipments which average as above. For preliminary work the following prices are used:

90 per cent. lime, at $5.00 per ton=0.25c per pound.
95 per cent. soda ash, at $20.00 per ton=1.00c per pound.

PITTSBURGH TESTING LABORATORY METHOD.
FOR
CALCULATION OF CHEMICALS REQUIRED
FOR
WATER SOFTENING,
AND
NEUTRALIZATION OF ACID WATERS.

Basis: Add one equivalent of lime for free carbon-di-oxide, insoluble lime, insoluble magnesia, soluble magnesia and free acid. Insoluble magnesia requires *two* equivalents of lime.

Add soda enough for soluble lime and soluble magnesia and free acid.

Iron present as carbonate is removed by the addition of an equivalent of lime.

Parts per 100,000		Pounds for 1,000 U. S. Gallons.
CaO, insol. (*i. e.*, as carbonate)	x .0925	=Com'l lime, 90% CAO
MgO, insol. (*i. e.*, as carbonate)	x .26	" " " "
MgO, soluble (*i. e.*, as sulphate)	x .13	" " " "
MgO, soluble (*i. e.*, as chloride)	x .13	" " " "
MgO, soluble (*i. e.*, as nitrate)	x .13	" " " "
Acid, free (calculated as H_2So_4	x .053	" " " "
CO_2, free	x .118	" " " "
Fe (as carbonate)	x .093	" " " "
CaO, soluble	x .166	=Soda ash, 95% Na_2CO_3
MgO, soluble	x .233	" " " "
Acid (free)	x .095	" " " "

At 15° C., saturated limewater=1.3 g. per liter.
At 15° C., saturated limewater=1.083 lbs. per 100 gallons.

These two figures should be verified for each water before final calculation.

ARCHBUTT'S METHOD FOR CALCULATION OF CHEMICALS REQUIRED FOR WATER SOFTENING.

"As much sodium carbonate is dissolved in a little water as is equivalent to the total lime and magnesia, deducting as much as is equivalent to the total alkalinity of the water."

Lime water enough is added to give a straw color with silver nitrate, and then as much more as is equivalent to the magnesia present. This would, apparently, lead to the same results as would be obtained by our method of caiculation.

Returning to a further consideration of the method in which it is best to state the results of chemical analyses of water, it may be admitted that the simple statement of basic and acid radicals acually found will be safest and wisest in some cases.

In a very great number of instances, however, the client desires to have the analysis show the most probable combination of bases and acids. He wishes to know what salts are in the water, so that its medicinal or technical uses may be intellingently understood.

For this reason it is desirable that chemists should get together and agree upon a method of expressing results.

Cairns, "Quantitative Analysis," 1888, p. 182, follows this plan, which he says meets most cases:

Combine the sodium with chlorine as sodium chloride and the potassium with sulphuric acid as potassium sulphate. Should there be any more sodium than chlorine, and more sulphuric acid than is required by potassium, combine the excess with sodium, and if there is more sodium left, combine it with carbonic acid.

Should there be more than enough sulphuric acid for both sodium and potassium, combine excess first with calcium as calcium sulphate, and next with magnesia as magnesium sulphate.

If chlorine is more than enough to satisfy sodium, combine it with potassium if sulphuric acid was not sufficient.

If chlorine is still in excess, combine it with magnesium and

then with calcium. Calculate all calcium and magnesium, not combined with chlorine, and sulphuric acid, as carbonates.

This method may be criticised in that it makes no provision for nitric acid if present, and that it does not take advantage of the absolute knowledge which may be gained by analysis, as to the amounts of calcium and magnesium present as carbonates. The method is based on Fresenius's earlier recommendations. In the latest* edition of Fresenius the following example of a water analysis calculation is given. The author determines the *calcium* precipitated by boiling, and calculates it to carbonate. Beyond that he attempts to combine acids and bases according to relative affinities and solubilities:

1. Barium calculated to sulphate of barium.
2. Strontium calculated to sulphate of strontium.
3. Residual sulphuric acid calculated to calcium sulphate.
4. Bromine calculated to magnesium bromide.
5. Iodine calculated to magnesium iodide.
6. Calcium not precipitated by boiling, and not already figured to sulphate, is calculated to chloride of calcium.
7. Potassium calculated to cloride of potassium.
8. Lithium calculated to chloride of lithium.
9. Ammonia calculated to chloride of ammonium.
10. Sodium calculated to chloride of sodium.
11. Residual chlorine calculated to magnesium chloride.
12. Phosphoric anhydride calculated to phosphate of calcium.
13. The calcium found in the precipitate on boiling, minus the amount required by phosphoric acid, is calculated to carbonate.
14. The magnesium not calculated to bromide, iodide or chloride is figured to carbonate.
15. The iron found is calculated to carbonate.
16. The manganese found is calculated to carbonate.
17. The silica found is calculated as silica.
18. The free carbonic acid is calculated by deducting from

*"Traite de l'Analyse Quantitative," R. Fresenius, 7th French from 6th German ed., 1900.

the total the amount required by the lime, magnesia, iron and magnesia to form bicarbonates.
phate of alumina. In saline waters it is figured as phosphate of calcium.

The scheme given above was used in connection with a mineral water analysis. No provision is made for nitric anhydride.

FRESENIUS'S GENERAL RULE FOR WATER ANALYSIS CALCULATION.

This is supposed to apply to technical analyses where the rarer elements are not determined and is given in the 1900 edition.

If the water is alkaline all of the calcium and magnesium present are calculated as carbonates. Otherwise proceed as follows:

1. Combine all chlorine with sodium.
2. Combine excess chlorine with calcium.
3. Combine sulphuric acid with calcium.
4. Combine nitric acid with ammonium, and then with calcium or magnesium, if necessary.
5. The remaining lime and magnesia are calculated as carbonates.

This rule is very incomplete, in that it does not provide for the disposal of the sodium which might be in excess of the chlorine. It is also silent on the disposition of sulphuric acid in excess of the amount required by calcium, and of nitric acid in excess of the amounts required by the bases enumerated. The first illustration is much more complete.

There seems to be a feeling among the followers of Fresenius that in general the sodium and potassium should be the first bases to be provided for, and they are generally given the chlorine or sulphuric acid, or both if necessary.

The method of analysis used in the Kennicott laboratories is shown on a chart recently sent out for criticism. It differs from plans in general use, in that it provides for the determination of the amount of calcium sulphate actually present. This is accomplished by the use of alcohol of .92 specific gravity as a solvent for treating the dry residue. Silica, carbonates of lime and magnesia and sulphate of lime are insoluble in this menstruum.

They are afterward separated, the determination of sulphuric anhydride being the index to the amount of calcium present as sulphate.

This removes one more arbitrary step from water analysis calculation, but it is accomplished at the expense of some time and considerable alcohol. It does not affect water softening calculations at all, but it is designed to give certain information regarding the most important scale-forming compound which occurs in waters. The actual value of the alcohol used for each analysis would be from six to ten cents, which is not so serious a matter as would at first appear.

The fact that three hours are required for the extraction, indicates that sulphate of soda and the other soluble salts do not dissolve rapidly, and errors due to incomplete extraction would have to be guarded against by tests, as suggested.

The scheme makes no provision for calculation of nitrates, but it seems to the writer to be commendable in other respects.

If the plan could be elaborated further to allow discrimination between magnesium chloride, sulphate and nitrate, nothing would be left to the analyst's judgment. This, however, is hardly to be hoped for, and it is, therefore, desirable to have the necessarily arbitrary calculations all made by the same method.

Order in Which Bases Are Apportioned to Acids by Severay Analysts.

	Sulphuric Acid.	Chlorine.	Nitric Acid.
Cairns.....	1. Potassium.	Sodium.	.....
	2. Sodium.	Potassium.	.....
	3. Calcium.	Magnesium.	.....
	4 .Magnesium.	Calcium.	.....
Fresenius.....	1. Barium.	Calcium.	.....
	2. Strontium.	Potassium.	.....
	3. Calcium.	Sodium.	.....
	4.	Magnesium.	.....
Pittsburgh Testing Laboratory.	1. Calcium.	Calcium.	Calcium.
	2. Magnesium.	Magnesium.	Magnesium.
	3. Sodium.	Sodium.	Sodium.
	4. Potassium.	Potassium.	Potassium.

	1. Calcium.*	Calcium.	.....
Kennicott.....	2. Magnesium.†	Magnesium.	.....
	3. Sodium.	Sodium.	.....

For technical work, direct determinations of sodium and potassium are not usually made. The residual acids not required for the bases found are calculated to sodium salts.

LABORATORY SOFTENING TESTS.

After obtaining a correct chemical analysis of any water which is to be softened, and making a calculation of the kind and amounts of chemicals required for its purification, it is best to soften a sample of water in the laboratory.

If, however, we simply mix the chemicals and water in the proper proportions and let the mixture stand, the completion of the chemical reaction will take many hours.

It is necessary to take advantage of the beneficial influence of agitation with crystalline sludge in order to determine quickly the correctness of our calculation.

The lime water used should be made from the water which is to be softened. If softened water is to be used in the lime saturator of the apparatus, it must also be used in the laboratory test.

One gram of crystalline sludge is mixed with about 250 c. c. of water plus the necessary reagents. The mixture is shaken vigorously for ten minutes or stirred for half an hour by mechanical means.

Filtration follows, and an aliquot portion of the filtrate is analysed to determine whether the lime and magnesia have been removed to the degree expected. The soap test, the alkalinity test, and the silver nitrate test will tell what change in reagents is necessary.

It must be remembered that free carbonic acid will exist in larger quantity in a fresh sample of water. The total amount of lime required for treatment must be determined on fresh samples, tested at the source.

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*Calcium calculated from sulphate insoluble in alcohol.

†Magnesium figured to sulphate is the amount left over after figuring the magnesium combined with chlorine.

The fact that the design of the machine depends upon the speed and completeness of the softening should not be lost sight of in a laboratory test. The period of stirring and time of standing practically quiet should be the same which is to be allowed in the machine. These factors can be varied if necessary.

It will then be possible to judge with sufficient accuracy what the rate of softening is, and from this what size of machine will be necessary.

In this "speed of reaction" experiment not over 0.2 gr. of sludge should be present for 500 c. c. of mixture.

CHEMICAL CONTROL OF SOFTENING PLANTS.—DETERMINATION OF HARDNESS.

Soap Solution.

Dissolve 13 grams of pure, powdered castile soap in one liter of 50% alcohol (half alcohol and half water). Let stand over night and filter.

Standardization.

Dissolve one gram of pure calcium carbonate in a slight excess of dilute hydrochloric acid. Evaporate to dryness. Dissolve in boiled, distilled water; make up to one liter: 1 c. c. = .001 gm. of calcium carbonate.

Pour 12 c. c. of this solution in a stoppered bottle (perferably one of about 500 c. c. capacity, of square section and about twice as high as wide). Dilute to 100 c. c. with distilled water. Run in soap solution from a burette, shaking well after each addition, until there is formed a lather which is permanent for three minutes after opening the bottle and laying it on its side. Twelve c. c. of soap solution should be required. If less is needed, dilute the entire soap solution with 50% alcohol in the proportion indicated by the test.

The Hardness Test.

Place 100 c. c. of water in the bottle, add the soap solution as above. If more than 14 c. c. of soap solution is required, repeat the test, using 50 c. c. of hard water diluted to 100 c. c. with

Shipments are sampled as received. If in barrels, take three lumps from each of five barrels. If in bulk, select 15 lumps to represent the car load. Crack off approximately equal-sized pieces from each lump. Crush, mix, quarter and grind. Bottle half an ounce of the average sample after grinding to pass 100 mesh.

Weigh out 0.28 gram. Place in an erlenmeyer flask exactly 100 c. c. of 10% cane sugar solution. Add the lime to this, shake until no further solution is apparently taking place. If any lime sticks to the bottom it will be slow in dissolving. Sticking can be avoided by continuous and rapid movement of the liquid.

Filter 50 c. c. and titrate with decinormal sulphuric acid. Multiply c. c. used by two. Result shows per cent. of available calcium oxide, which is the measure of value of the lime when used for water softening.

Analysis of Soda Ash.

Dissolve 0.53 gm. of a well mixed average sample in water and make up to 100 c. c. with cold distilled water. Titrate 50 c. c. of this with d. n. sulphuric acid, using methylorange as indicator. Multiply c. c. of acid used by two to get percentage of sodium carbonate in the soda ash.

Municipal Water Softening Plants.

THE MUNICIPAL SOFTENING PLANT AT SOUTHAMPTON, ENGLAND.*

The city of Southampton, England, with a population of about 70,000, is supplied with water, softened by the Clark process. The plant is continuous in operation. It was installed in 1888, and was worked for several years according to W. Geo. Atkins' plans. It was designed for 2,500,000 imperial gallons per day. It has been modified by Mr. William Matthews so that it now treats 4,000,000 gallons per day.

Silver Nitrate Test.

Silver nitrate gives a yellow color or a brown precipitate when added to water containing free calcium hydrate. This is useful in connection with alkalinity and hardness tests. If the alkalinity to the phenolphtalein end point is above the normal, and the silver nitrate test shows a colored precipitate, too much lime is being used.

Examination of Lime Water.

Total Calcium Hydrate:—Draw a sample of about 50 c. c. of lime water. Unless clear add approximately 5 grams of cane sugar. Cork the bottle and shake for two minutes. Filter through a dry paper into a dry vessel. Titrate 21 c. c., with decinormal sulphuric acid, using phenolphtalein indicator. If approximately 10 c. c. of acid are required the lime water is of full strength or 100%. If more than 10 c. c. of acid are required, the result shows calcium hydroxide in suspension as well as solution. Such a state of affairs indicates too large an excess of lime in the lime saturator, or too rapid or uneven a flow.

If 21 c. c. of lime water require less than 10 c. c. of acid, it is not saturated, and probably the lime supply is low. This relation of 21 to 10 varies somewhat with different waters, and should be determined under actual conditions always.

The use of sugar as a solvent for calcium oxide in connection with the analysis of *quick lime* was suggested by Stone and Scheuch in 1894.* The originators of the method used methyl-orange or rosolic acid. We prefer phenolphtalein as indicator.

Oxide and carbonate of magnesia are insoluble in sugar solution, and carbonate of lime is not appreciably soluble.

Analysis of Lime.

Lime will be received in barrels or in bulk, according to the amount used. It should be stored in a dry room, preferably one lined inside with metal sheathing.

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*"A Method for the Determination of Calcium Oxide in Quicklime," Jour. Am. Chem. Soc., 1894, p. 721, Stone and Scheuck.

distilled water. If more than 14 c. c. is still required, use 25 c. c. of the original water and dilute to 100 c. c. for test.

The cubic centimeters of soap solution used for 100 c. c. of water indicate the hardness expressed in parts of calcium carbonate per 100,000. (This represents Kennicott practice, except that we have recommended preparing calcium chloride from the carbonate.)

Determination of Alkalinity.

One hundred c. c. of treated water are titrated with decinormal sulphuric acid, using successively phenolphtalein and methylorange as indicators. The second end point is best taken when the clear yellow solution just changes to orange on its way to a clear pink. The methylorange solution is made by dissolving 0.1 gram of the powdered material in 100 c. c. of 50% alcohol. For general work this gives very satisfactory results. For more exact work in the laboratory use the method given below for alkalinity or acidity. For alkalinity tests of hard water only methylorange indicator is used.

Determination of Acidity.

Titrate 100c. c. of water with d. n. sodium hydrate, using phenolphtalein as indicator. This gives the acidity due to free sulphuric acid, sulphate of iron and free carbon di-oxide. As the latter is usually quite small in amount, it is disregarded in control work at softening plants.

Alkalinity or Acidity Determination.

In order to get the acidity or alkalinity of a water most accurately, it is best to add to 100 c. c. of water a measured excess, e. g., 5 c. c. of d. n. sulphuric acid. Add three drops of phenolphatlein solution, boil twenty minutes in a porcelain or a platinum dish, cool and titrate with d. n. sodium hydrate. The increase in acidity is the measure of the acidity of the water. The decrease in acidity is the index to the alkalinity of the water. By "measured excess" of acid is meant acid in excess of that required by direct titration with sodium hydrate when using methylorange as indicator.

The plant and the method of operation in August, 1901, were reported to be as follows:

Lime burned in two kilns from chalk quarried on the premises is stored in a moisture-proof room. Measured quantities are periodically slaked in a revolving cylinder with a definite amount of water and pumped to the lime water tanks, of which there are four, each being 11′ high by 9′ in diameter and terminating in a 3′ cone at the bottom.

They hold about 1 hour's supply of lime water, but are furnished with lime cream enough at one time to last six hours, the lime water being formed by running water through.

Softened water from the high pressure main is used for making lime water. Two pounds of lime are required per 1,000 gallons of water softened. The water is reduced from 18° hardness to about 5°. With such cheap lime the repumping of 12% of the water for making lime water is a very questionable economy. Matthews claims that lime water made with soft water clarifies sooner. We did not find it so.

The proportion of lime water to hard water is regulated by weirs, but not automatically. The weirs simply indicate the rates of flow, and by valves the ratio is kept as it should be. This method may have been replaced by the use of a proportional pumping device.

No chemical tests of lime water are made to ascertain whether things are going right. Only the most uniform lime supply and rate of pumping could make success possible under these conditions.

The hard water and lime water are mixed by flowing through a passage with baffles, and the mixture then falls into the "Softening Tank," 44′ x 76′ x 6½′ deep. A baffle wall makes the course of the water first down nearly to the bottom and then forward some 70 feet to the filter house. The tank holds only about 135,000 gallons, which at a 4,000,000 gallon per day rate, means only about 50 minutes' supply. This is a remarkably short time for

*"Water Softening at Southampton," J. H. Fuertes, Eng. Rec., Feb. 2, 1899.

†"Southampton Water Softening Plant," Matthews, Proc. Inst. Civ. Engrs., Vol. CVIII., 1891-2.

chemical action, but the water is reported clear and tasteless after filtration, and showing no after-reaction.

The filters seem to be rather cumbersome, but are remarkably efficient. They are of Atkins' design. Nineteen are used. According to Fuertes, each filter consists of a hollow shaft, having longitudinal slots, on which is mounted a series of perforated zinc discs 3′ in diameter and separated from each other by collars. Over the disks cotton cloths are stretched and held by iron rings pressed over edges. There are twenty disks and forty cloths to each filter.

The filters are placed in iron tanks, one end of the shaft passing through a stuffing box and communicating with the small filtered water basin below. The shaft and disks may be rotated by gearing, and the whole may be lifted out by an overhead crane, when the cloths are to be replaced.

The filters thus work, submerged in water, filtering inward, and they have to handle practically three tons of precipitate daily, because little, if any, settles in the large tank. When clogged, the filter-tank is drained and the cloths rinsed off with water from a hose, the sludge and excess water being separated in tanks below. The water is pumped back and the sludge run to waste.

The cloth used for the filters is a cotton of medium weight and weave, and of somewhat rough finish. Its life averaged three months when 3,000,000 gallons of water were being used daily. This meant 50 square feet of cloth per day on 5,000 square feet in use.

This high duty of the filters under practically no head would not be possible for a moment if the water were magnesian, as it is at Winnipeg. Our sludge is like lard in smoothness and fineness, while the Southhampton sludge is all crystalline calcium carbonate. It is probable that the great speed and completeness of the softening are made possible by the presence of the clean crystals of carbonate of lime in suspension in the water during the whole time in the tank, and also by the passage of the water through the crystals on the cloths. If the water had contained magnesia as well as lime, the whole process would have gone quite otherwise.

The cost of softening at Southampton is said to be only one

cent per 1,000 gallons. Lime costs them approximately 0.25 cents per 1,000 gallons. The investment originally was £10,000, and there have been improvements since then. The interest and depreciation charges would be 0.84 cents. Repumping, say, 12% of the water means 360,000 gallons raised from filtered water basin to top of lime water tanks. The lift would be about 25′, and the cost not less than 0.12 cents per 1,000 gallons *output*. There is the waste of water in the sludge and the cost of power used about the plant for running the lime slaker, lime pump and sludge pump. Beside these items the labor cost cannot be less than 0.3 cents per 1,000 gallons.

We do not see how the cost can fall below 2 cents per 1,000 gallons of water softened, but even at this figure the result reflects credit on the designers of the plant.

MUNICIPAL SOFTENING PLANT AT WINNIPEG, MANITOBA.

In September, 1897, Mr. Rudolph Hering, C. E., made a report to the city of Winnipeg, Manitoba, on a "Future Water Supply." The city authorities at that time were considering the purchase of the plant of the private company which had been supplying them with Assiniboine river water.

The river supply had been of unsatisfactory character, and Mr. Hering was asked to compare all available sources. His examination satisfied him that the artesian supply undoubtedly to be had just west of the city would be the cheapest and best, but that it would be necessary to soften the water. The total expense was still calculated as sure to be less than that of bringing soft water 50 miles from the Winnipeg river.

The advantages of soft over hard water for a community were stated by Mr. Hering as follows:

"Hot water is obtained more quickly and less fuel is required. The saving of soap and soda in the household is considerable. The labor of washing is much reduced. The wear and tear of clothing is diminished. Flannels last longer and do not become harsh and felted. Cooking is facilitated. The same quantity of tea that will make three cups with hard water will make five cups with soft water. (Evidence before Royal Commission.) The

palatability is often increased. The softening process does not make water insipid."

Mr. Hering estimated the cost of softening the artesian well water at 2.57 cents per 1,000 gallons, and the cost of a softening plant at $27,000, exclusive of the building. It would cost a family of five persons using 300 gallons of water daily less than 1 cent for softening, and if 100 gallons of this were used for washing purposes, 1 1-3 pounds of soap, worth, at least, 7 cents, would be saved.

The city council of Winnipeg accepted Mr. Hering's recommendations, and in the spring of 1899 advertised for bids for pumping engines, boilers and a softening plant.

A few railroad and industrial softening plants had been built in the United States up to that time, and in England the Southampton municipal plant was in existence. The idea was, however, new enough in both the United States and Canada, so that the city engineer, Col. H. N. Ruttan, had to personally solicit bids in order to have any competition. Four were finally secured, and the offer of the Pittsburgh Testing Laboratory, Limited, was accepted.

The city water in its natural state, has a temperature of 42°F, and is of the following composition:

	Parts per 100,000.
Free carbon dioxide	2.20
Silica	.28
Carbonate of lime	20.30
" " magnesia	11.30
" " soda	3.99
Sulphate of lime	0.60
" " magnesia	17.25
" " soda	6.59
Chloride of sodium	39.60
Total solids	99.91

Temporary hardness=23.63° (Clark's scale).
Permanent hardness=10.37° (Clark's scale).
Total hardness=34.00° (Clark's scale).
Maximum hardness removable by lime process, 23.63°.
Maximum hardness actually removed by P. T. L. Plant, 22.73°—96.2%.
Average hardness removed, 24-hour test, 21.28°—90.1%.

CAPACITY OF PLANT.

The plant was guaranteed to have a capacity for softening 2,400,000 imperial gallons (2,880,000 U. S. gal.) per day, and to furnish softened water at a rate 50% greater than this for several hours when required. We not only ran successfully for four hours at the highest guaranteed rate, 3,600,000 gallons per day, but also ran up to a 4,000,000 gallon rate for a shorter period. The degree of softening was 22.2°, at the 3,600,000 gallon rate. This was 93.99% of the result theoretically possible. The chemical reaction was equally satisfactory at both high and low rates of running. The filter capacity was, however, more severely taxed when the rate exceeded 2,400,000 gallons in 24 hours.

PROCESS ADOPTED.

It was decided that the softening process should be limited to the removal by lime treatment of the maximum possible amount of the bicarbonates of lime and magnesia from the water, leaving the magnesium sulphate undisturbed. For this purpose the Clark process was used.

The chemical basis of the method is as follows: Water falling as rain dissolves some carbonic acid gas from the atmosphere. It takes up more of the gas as it sinks into the soil, and when it is in a country where it comes in contact with limestone, which consists of carbonate of lime and magnesia, it dissolves some of the carbonates out of the rock and becomes a hard, soap-destroying and scale-forming water. This result is made possible by carbonic acid gas. If now any substance can be added to this hard water to absorb the carbonic acid, the carbonates of lime and magnesia which it held in solution are set free and fall as a white precipitate out of the water, leaving it nearly as soft as it was originally.

Two chemical agents are capable of doing this. One is sodium hydroxide, commonly called caustic soda, and the other is calcium hydroxide, commonly called slaked lime. The treatment by soda costs 14 times as much, and is objectionable for other reasons. Therefore, the lime process is used. Builders' lime is made by driving off the carbonic acid from limestone in kilns. It

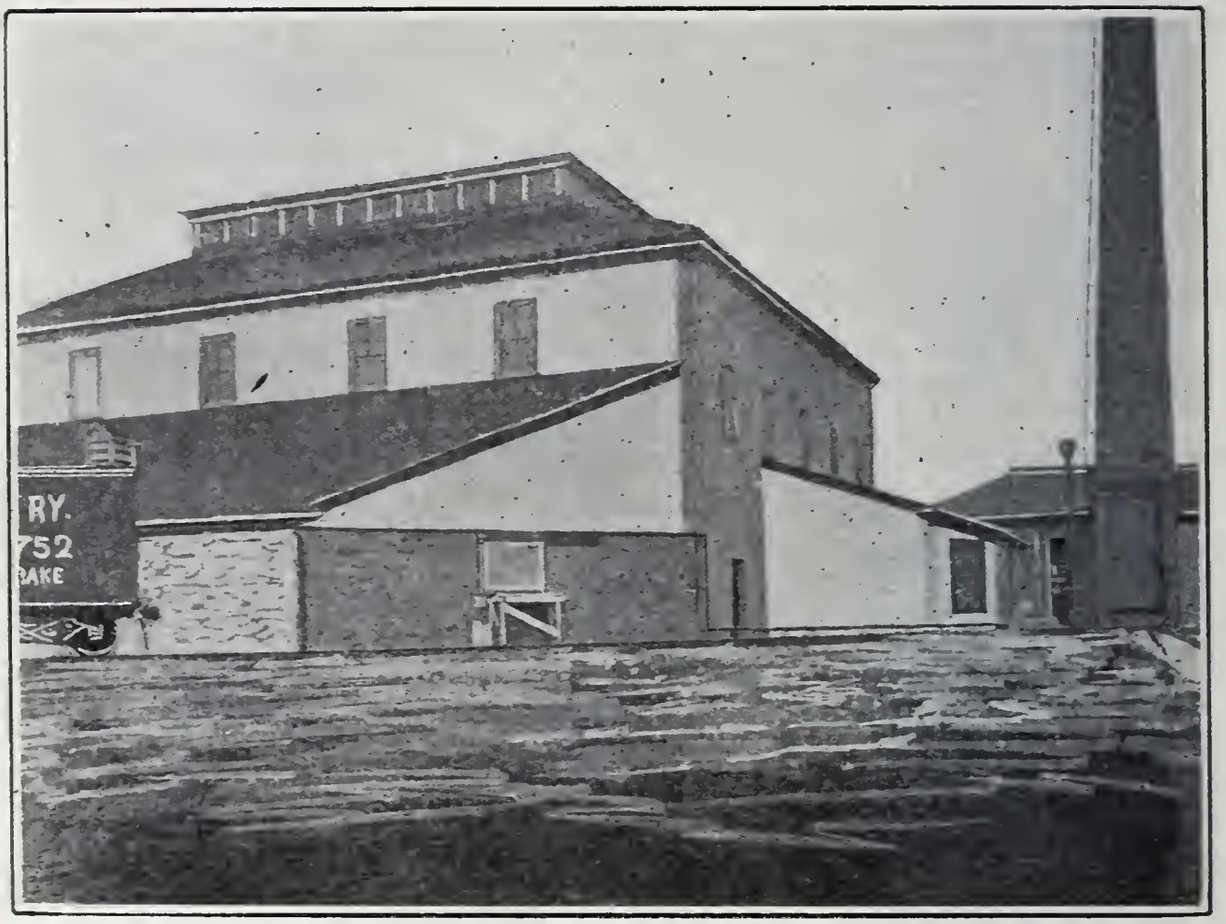
has a great affinity for both water and carbonic acid. When uniting with water to form calcium hydroxide heat is developed. The process is called slaking. After the slaking the calcium hydroxide still retains its affinity for carbonic acid. If added to hard water it unites with this gas with great avidity, forming an insoluble compound (carbonate of lime) which separates from the water. At the same time the carbonates of lime and magnesia which were held in solution, in the hard water by the carbonic acid, are set free, and they also settle out of the water if allowed proper opportunity to do so.

Calcium hydroxide (slaked lime) is only sparingly soluble in water. Hence in applying it for water softening purposes it is sometimes used in mixture with water as cream or milk of lime. This is the form in which it is usually employed in the "intermittent" systems of water softening. In the continuous systems, however, advantage is taken of the fact that a saturated solution of lime in water (lime water) has a perfectly definite strength at any given temperature. This averages for cold water about 1.3 gm. per liter, or 1.083 pounds per 100 U. S. gallons, or 1.3 pounds per 100 Imp. gallons.

The problem at Winnipeg, therefore, was to apply the proper proportion of lime to the water in a uniform manner. This we accomplish as follows: Lime, purchased by the car load, is discharged into the lime store room shown at the corner of the plan. It is weighed out 375 pounds at a time, and slaked in a slaking bed with hot water, after which it is made up to a definite volume and run through a screen into the mixing well. Here it is kept in suspension by a stirrer operated by a 12 H. P. engine, also used to run the washing machine and blower and lime tank stirrers.

From the mixing well the cream of lime is forced up by means of a special ball valve pump to the weir box, where it meets the water which is to be made into lime water, and the mixture passes to the bottom of the two lime tanks.

Here a small excess of lime is maintained to take care of a sudden increase in rate of pumping. The lime tanks are 14′ in diameter by 18′ deep. They have cone bottoms inside and stirrers



WINNIPEG WATER SOFTENING PLANT.
View of lime room, sludge house, etc.
Figure 9.

with paddles, which revolve slowly in these cones, the idea being to maintain an even cream of lime at the bottom. Through this the nearly saturated lime water flows, and becoming saturated continues upward, clarifying as it rises. The impurities and excess lime theoretically remain behind, but actually a small amount of lime is always present in suspension, and in our method of chemical control this is always taken into account.

The lime water, made as described, overflows constantly at a point about five feet above the level of the reaction tanks, as shown. It passes forward through an 8″ pipe line and meets the hard water in a baffle channel just below the weir box which will be described later.

In the baffle channel the hard water and lime water are most thoroughly churned and mixed together. The softening process begins instantly and is perhaps nine-tenths finished before the water divides and passes into the two 20′ x 30′ reaction tanks.

It enters these through chutes, the proper shape for which was only determined after much experiment. Each chute, 22″ in diameter, conveys the water to a point 36″ from the tank floor and turns sidewise, following the curve of the tank for ten feet, gradually flaring out to a flattened oval, 3 feet wide by 1 foot high.

Into the quiet area below the chute, most of the precipitate settles at once. All but a trace of the remainder, so far as appearance goes, settles out during the rise of the water through the tanks.

The nearly clarified water flows off through floating draw-off pipes at the top of the tanks. These pipes have T shaped slotted pipes, extending over the surface of the tank to make a more even draught, and to avoid eddies.

The water, now under about 17′ head, flows to the filter presses, which clarify it perfectly. These presses are of special design and of capacity probably unequalled for their size. Their duty is to remove a minute amount of precipitate rapidly from a very large volume of water—just the reverse of the work of an ordinary filter press. There are seven presses, 15′ x 3′ x 3′, and each one has 80 plates. Cloths, made of 10 oz. duck, are placed

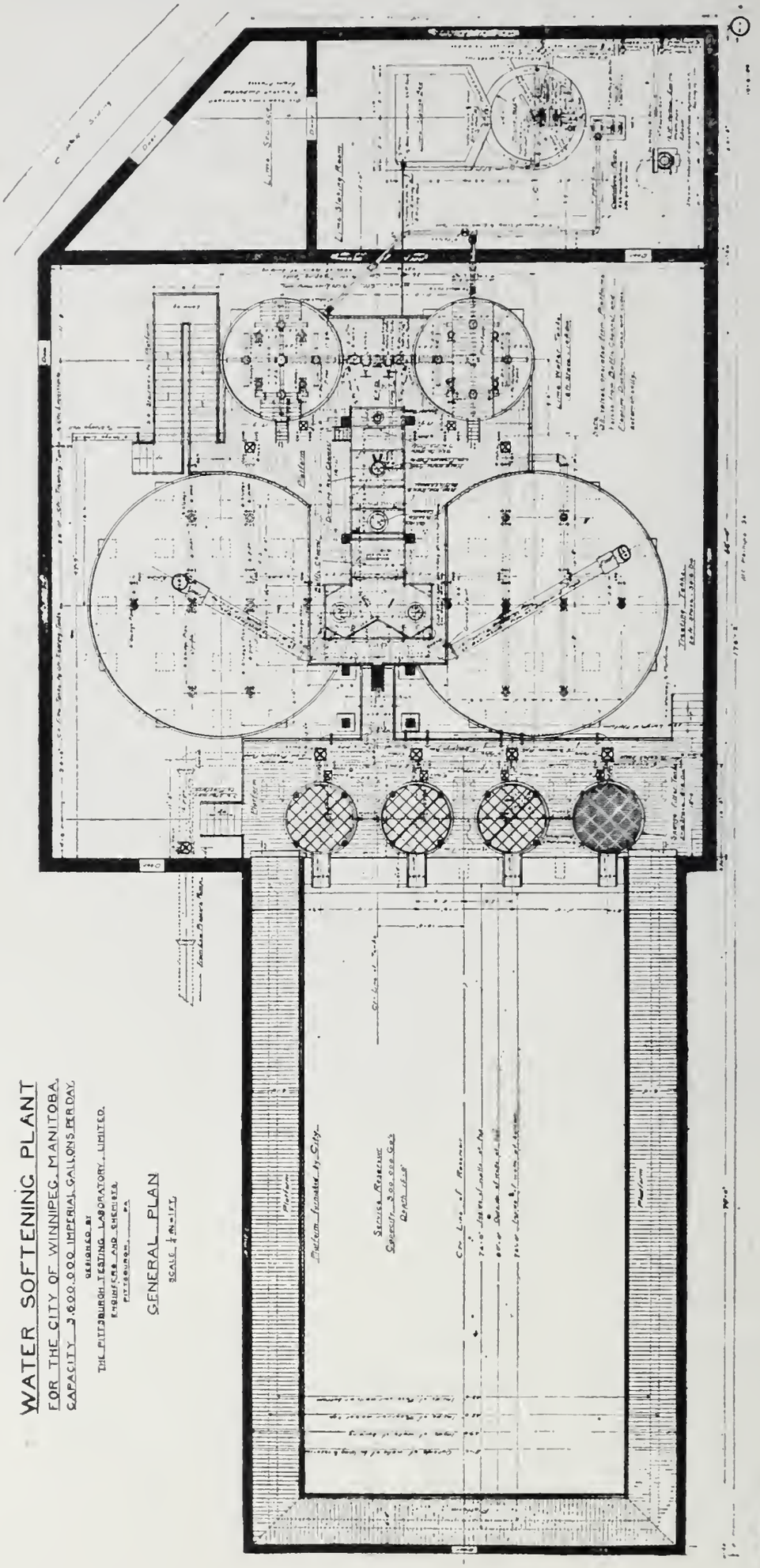

WATER SOFTENING PLANT
FOR THE CITY OF WINNIPEG, MANITOBA.
CAPACITY 3,600,000 IMPERIAL GALLONS PER DAY.
DESIGNED BY
THE PITTSBURGH TESTING LABORATORY, LIMITED.
ENGINEERS AND CHEMISTS
PITTSBURGH, PA.
GENERAL PLAN
SCALE 1/8 IN. = 1 FT.

Figure 10.

WATER SOFTENING PLANT
FOR THE CITY OF WINNIPEG, MANITOBA.
CAPACITY 3,600,000 IMPERIAL GALLONS PER DAY
THE PITTSBURGH TESTING LABORATORY, LIMITED.
CHEMISTS AND CHEMICAL
ENGINEERS
PITTSBURGH, PA.
GENERAL ELEVATION
SCALE 1/8 INCH

Figure 11.

over each frame, giving a total filter surface, after deductions for holes, etc., of about 1,000 square yards. These filters run from 24 to 48 hours before cleaning is necessary, the average number being two or three filters cleaned for each 24 hours' run. This means a 500,000 gallon delivery for each filter between cleanings.

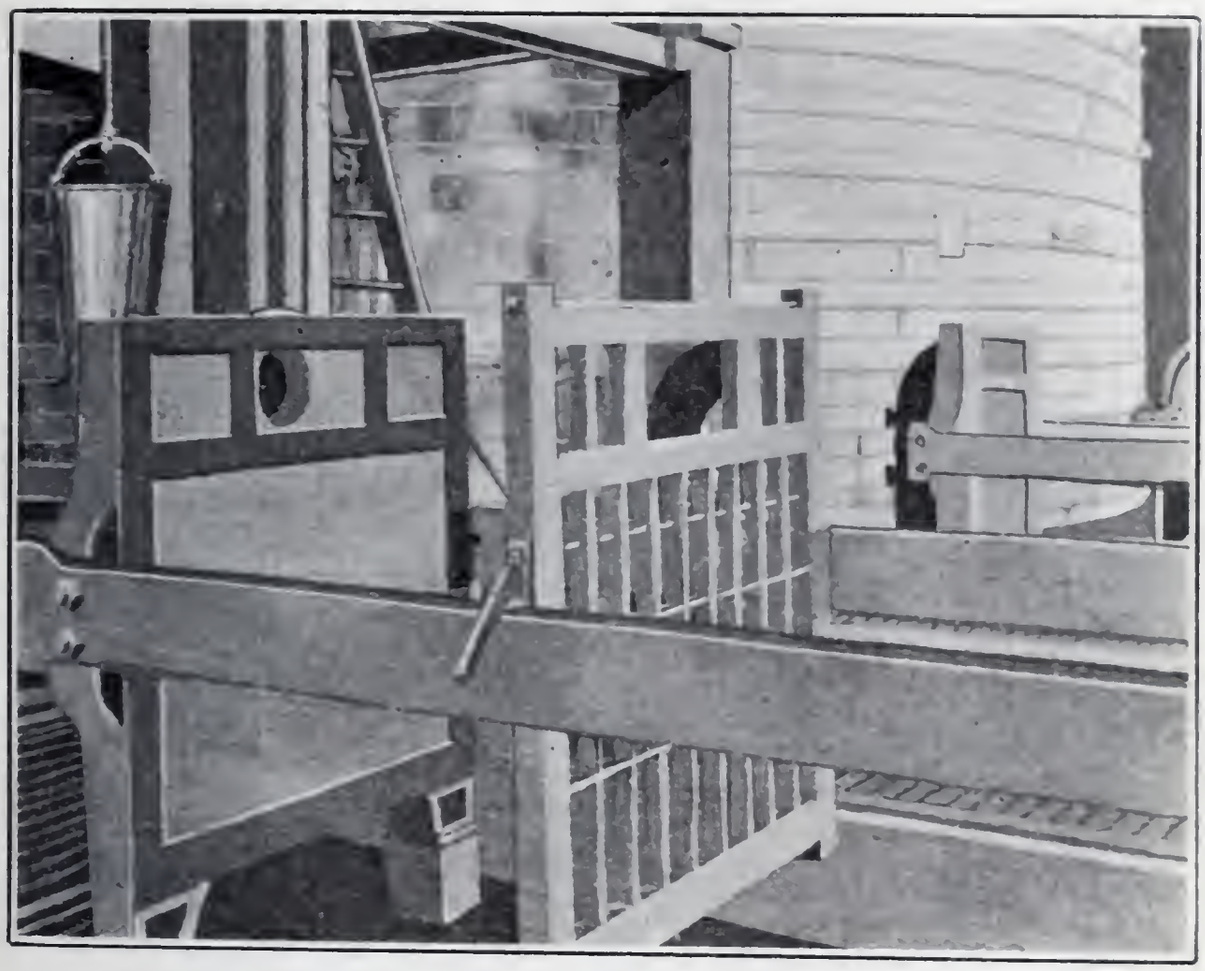
The water passes into the presses at the ends, and finds a continuous opening through all the plates the length of the press. From this channel it must find its way down between the cloths, then through any cloth into the open grill work of the frames, from which it drops out into a trough discharging into the carbonating box. The object of carbonating is explained further on. The method is as follows. The process and apparatus were devised by the writer:

THE CARBONATING PROCESS.

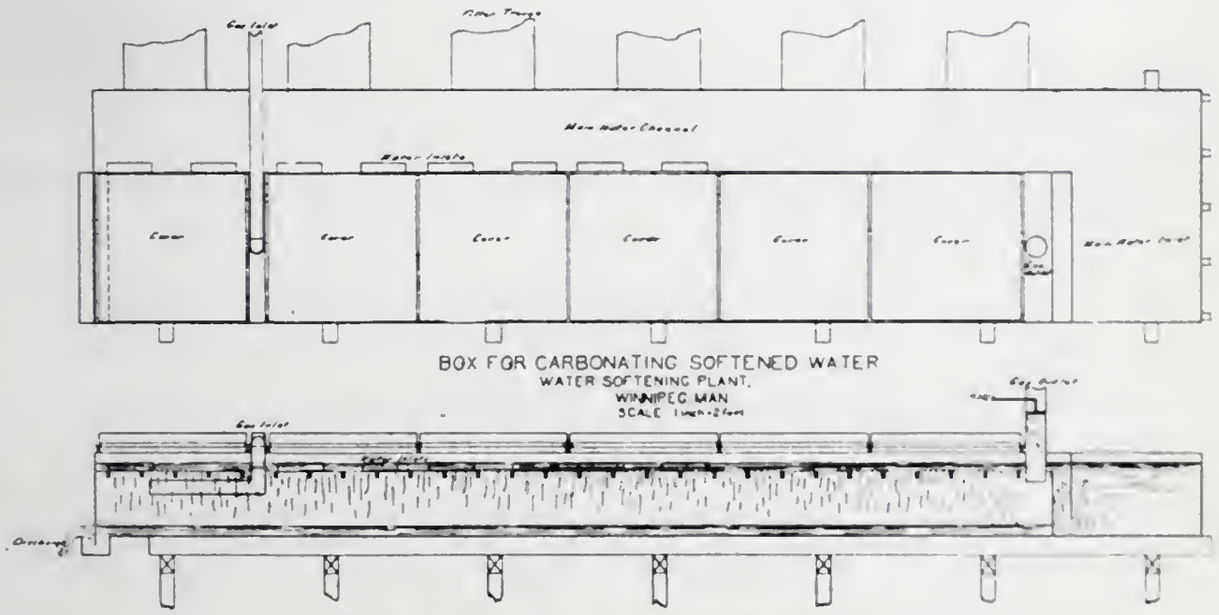
Coke is burned in a small brick furnace. The gases are drawn by a Buffalo blower and exhauster through a water-jacketed condenser or cooler. From the blower the gases pass to a wooden wash tank, where the sulphurous acid is removed by streams of water dripping over 2 feet of coke on a shelf. The wash tank is 6′ high by 6′ in diameter. Water enters through a copper spraying nozzle above the coke and flows off through a trap at the bottom. The gases enter just below the coke and pass away at the top by a wooden pipe, which conducts them to the carbonating box.

The carbonating box is placed across the end of the reservoir next to the filter presses. The water flows from the filters into a distributing trough, 3′ deep by 40′ long by 2′ wide. From this it flows through gas seals on to a perforated shelf, 6′ x 35′, with sides 8″ high. The shelf is made of heavy gauge galvanized iron punched with 3/32″ holes, the burr being left on to prevent the streams of water from running together. There are about 360 holes per square foot, or 73,000 all together. These carry a 3,600,000 gallon rate easily.

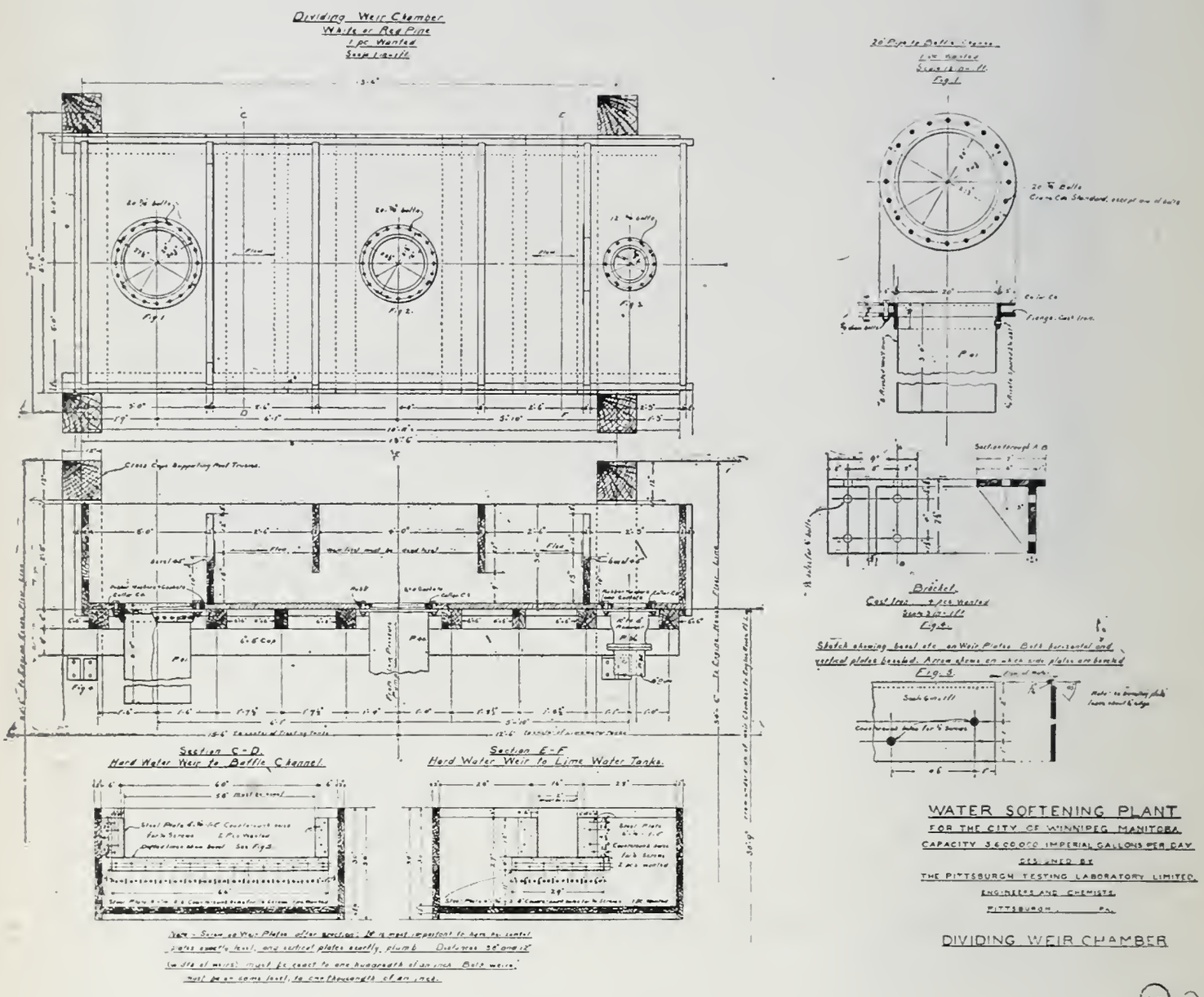
The greater part of the water flows onto the shelf at one end. A small part is introduced through openings along the side. This was done in order to cover the shelf evenly in spite of the great variations in pumping rate.



WINNIPEG WATER SOFTENING PLANT.
Details of filter press construction.
Figure 12.



WINNIPEG WATER SOFTENING PLANT.
Box for carbonating softened water.
Figure 13.



WINNIPEG WATER SOFTENING PLANT.
Dividing Weir Chamber.
Figure 14.

Six water-sealed covers enclose the perforated shelf, so that the gases entering below the shelf near the exit end of the box are forced to travel the whole length of the box through the small streams of falling water. This is more clearly apparent from the drawing.

The gases can come into the space above the shelf, but there is no exit for them there, and hence no circulation. The current of gas, therefore, passes through the box below the shelf, and the carbonic acid is very effectively dissolved by the falling water before the gas-exit pipe is reached.

This method of carbonating was the result of a very long series of experiments by the author. Conditions required that the carbonating should be completed while the water was on its way from the filters to reservoir. The available fall was very slight. Complete carbonating is effected in a 2′ 4″ fall in this apparatus.

The carbonating plant was installed by us after the plant had been accepted by the city of Winnipeg. After-reaction had produced slight but annoying incrustations on the valves and condenser of the pumping engine. These deposits were the cause of sticking valves or imperfect vacuum. In a few instances deposits on meters, etc., in the city proper, took place.

The carbonating process, by changing the water from alkaline to neutral, made it impossible for any after-reaction to take place. Trouble from that source ceased at once. The water was absolutely tasteless when carbonated.

The service reservoir, into which the softened and carbonated water discharges, holds 300,000 gallons when filled to a depth of 15′. From the far end of it the water is drawn off by high-duty Worthington pumps and forced directly into the mains. There is no stand pipe or auxiliary reservoir, so that the engines, in maintaining a uniform water pressure in the mains, have to meet the greatest variations in rate of consumption, and the softening plant had to be made to operate satisfactorily under such conditions. At times of fire or a break in the main the pumping rate would necessarily be the maximum, and the work required of our plant especially severe.

It was not the high rate of pumping but the great changes

in rate which made difficulties for us. How we met these troubles will be related further on.

The weir box, designed by Mr. Bellows, is one of the best features of the plant. It insures an absolutely proportional lime water treatment.

It consists of a box 15′ long x 6′ wide x 2′ 6″ deep, located 33′ above the floor of the plant. Into the bottom of this comes the hard water through a 16″ rising main. Baffle plates take the wave motion out of the water and then it flows uniformly over two weirs near opposite ends of the box. The weir openings are faced with adjustable, steel side-plates. The weir blades are exactly 15″ above the bottom of the box. The best ratio of lime water to hard water having been found by analysis and experiment to be 18:82, the weirs were set in this ratio, the combined width of the two being $70\frac{3}{4}$″.

The water falling over the lime water weir meets immediately a stream of cream of lime sufficient to saturate it under normal conditions. This lime water flows down through a 10″ pipe and continuously displaces lime water already made and clarified in the two lime water tanks previously described. If 300 gallons of water go over the lime water weir, 300 gallons of saturated lime water flow forward from the top of the lime water tanks and meet an exactly proportionate amount of hard water flowing from the weir-box through a 20″ pipe into the baffle-channel. Here they mix and go forward to the reaction tanks as described. It is impossible to get the wrong proportion of lime water. With a fairly uniform pumping rate it would be easy to keep the lime water of exactly even strength, *i. e.*, always at the saturation point. As the rate of pumping varies widely, some chemical supervison is necessary, such as occasional tests of lime water and variation of the speed of the cream of lime pump to suit the changing conditions.

We placed on the side of the weir box a gauge graduated to tenths of an inch.

The fluctuations between 2.5″ and 6″ covered the range between 1,000,000 gallons and 3,750,000 gallons per day. A small box with a 1″ weir served to measure the cream of lime flow. We

put a gauge on this as well and found that the feed was proper if the cream of lime gauge reading was kept at half that of the main weir gauge. It was only necessary to adjust the cream of lime feed at intervals. The strength of the cream of lime was about .5 pounds actual calcium oxide per U. S. gallon.

The lime water was tested every hour or oftener if unexpected fluctuations in pumping occurred. Samples for test were drawn from points about 8′ above the bottom of each lime water tank, experience having shown us what the strength should be at this point in order to give saturated lime water on top. These were called "bottom" tests. Occasional "top" tests of finished lime water were also made, the method in all cases being as follows:

LIME WATER TESTS.

Two ounce samples of lime water were shaken in bottles with approximately 5 grams of cane sugar. This caused all suspended calcium hydroxide, (or active lime,) to go into solution, leaving sludge undisturbed. The solution was then filtered and 21 c. c. of the filtered lime water tested with standard deci-normal sulphuric acid, phenolphtalein being used as indicator. This test is simple and was quickly learned by the men. If 21 c. c. require 11.5 of acid, the strength is 115, which is proper for a "bottom" test. If the test shows less, more cream of lime must be turned on. If the test is higher than 115 turn off a little steam from the cream of lime pump, the valve being operated from the upper platform. The lime water tanks equalize all but the greater irregularities in the pumping rate.

TROUBLES.

In a large plant like the one at Winnipeg, troubles, which might pass unnoticed in a smaller plant, have to be reckoned with. There has never been any question as to the capacity of the plant to soften the guaranteed amount of water daily, but in order to insure smooth running we found it best to make certain changes from our original designs.

Our experience had been with intermittent plants and we designed ours at Winnipeg on that basis, making provision for

many automatic features. The feed changed from one reaction tank to the other when necessary. Before sinking to sludge level, the floating discharge pipes were made to automatically raise their open ends out of water. In refilling, these pipes became submerged again only when the tanks were nearly full, thus keeping sludge out of them. Special gridiron valves operated automatically, shut off the flow from each tank when the water sank to a certain level.

In spite of all these devices to overcome the bugbear of intermittent plants, the frequent opening and closing of valves, we decided to change our plant over to the continuous method of operation. A valve becoming coated with lime incrustation would stick occasionally or a sudden change in rate of pumping would make one tank fill before the other had properly emptied.

The changes required to make operation continuous were remarkably few in number. The chutes and draw-off pipes were added to, as already described, in order to effect more even distribution of incoming water and drawing off of the softened water. The other changes made were simply for the improvement of the plant. Cone bottoms were put in the lime water tanks to facilitate the drawing off of sludge and to make the process more uniform. Stirrers took the place of perforated pipes at the same time. The latter were designed to distribute the incoming water evenly through the layer of cream of lime, but did not do so satisfactorily.

Sponge filters we were obliged to abandon after a very thorough trial. We tried every combination of coarse and fine sponges we could devise. Sponge clippings were very inexpensive, and preliminary experiments were most satisfactory. We had four filter tanks 8 feet in diameter and 5 feet deep. The sponges were held between expanded metal sheets fastened on wooden grills, the upper grill being movable. The water was admitted below the sponges and passed out from spouts above to the reservoir. The filtered water for the first half-hour was clear as crystal. As soon, however, as sufficient sediment collected on the filter, it was either forced through by the compression of the sponges independent of the grills, or, if held very tightly by

the grills, something broke or the path of least resistance was followed and cloudy water resulted.

We tried several combinations of sponges and cloth, using the latter as a ring under the upper grill at the sides, where leakage past the grill sometimes happened. These experiments were only moderately successful.

Sand filters could not be considered, as the great room required, on account of their high resistance was not available, and the power for cleaning would add to the expense of operation. A sand filter working on ordinary river water delivers daily about 2,500 gallons of water per square foot, of filter surface. This would have meant an installation at Winnipeg of fifteen or more twelve-foot sand filters. The resistance of the gelatinous magnesian precipitate would have made frequent washings necessary and the waste of water would have been large.

We adopted the filter press idea and made a special design. Seven presses occupying a floor space of about 315 square feet did the work. The method of cleaning and filling these presses is as follows:

The wooden plates are held in the frame by the usual movable plate operated by a capstan head and screw. When a press is ready for cleaning, the end is drawn back for a few feet and the cloths with their contents are removed to the washing machine. New cloths are put in place at once and the press is ready for use. Two men, if expert, can make the change in about an hour.

The cloths are rinsed in a tank to remove most of the sludge, and then thrown into a rotary washer where the rinsing is completed. They are next given a bath of warm dilute muriatic acid, and then a final thorough wash with water.

The acid treatment is to prevent the cloths from becoming hard from crystallization of carbonate of lime, among the fibers. This material will not wash out and must be removed by acid. Its occurence does not seem to be due to lack of the usual time for completing the chemical reaction of softening, but to the peculiar composition of the Winnipeg water which makes the final few degrees of softening very sluggish, indeed.

This gave us trouble in another way. Softened water filter-

ed perfectly clear gave a deposit on the valves of the pumping engine and deposits in the condensers, as already described.

This after-reaction was very slight in amount as compared with the quantity of water passing. The plant for carbonating has already been described. It has worked very effectively, giving complete relief from all after-reaction. The degree of softening was changed but slightly, 21° instead of 22° being removed. The test for complete carbonating is the absence of color when phenolphtalein is added to the softened water.

We had much trouble in getting good lime in Winnipeg. Low grade magnesian lime was very plentiful and quite cheap, but its use was neither economical nor satisfactory. The first car loads of lime with which we were supplied contained only 45% of actual lime.

This interfered with the process from start to finish, doubling the labor and clogging the apparatus. It was found cheaper to import lime from the United States at a total cost for material, freight and duty, of about $11.00 per ton. As the plant uses about 3 tons of lime a day, the matter of recovering lime from the sludge would be a commercial proposition, and has received serious consideration from the city authorities. The writer devised a process for removing the magnesia, the objectionable constituent of the sludge, by treatment of the wet material with carbonic acid gas, (combustion gases). By this means all of the magnesia is brought into solution as carbonate while the lime is not affected.

The residual carbonate of lime is then to be dried in centrifugal machines and run through a rotary kiln, to be burned into calcum oxide.

This system will be an ideal finish to the softening process at Winnipeg. More lime comes out of the water than is put in and there will be lime to sell while the same lime originally causing the water to be hard is made the means of softening the water which comes afterward.

The magnesia may be recovered by heating the solution and sold as a bye-product.

ESTIMATE ON LIME RECOVERY FROM SLUDGE AT WATER SOFTENING PLANT, WINNIPEG, MAN.

1,500,000 gallon rate.

Lime used, 5100 pounds, at $11.00 per ton		$28 05
Coke used, 400 pounds, at 10.00 per ton		2 00
		$30 05
Cost of treatment of sludge	$25 00	

PRODUCTS.

(a) 1,500 pounds lime for sale	$ 4 50	
(b) 5,100 pounds lime for use		
(c) 900 pounds magnesia for sale	4 50	
(d) 400 pounds coke saved because kiln will supply gas for carbonating	2 00	
	$11 00	
Net cost of lime recovered for water softening	$14 00	

Daily saving due to lime recovery when running at 1,500,000 rate = $16.05 or 1.07 cents per 1,000 gallons.

When running at 2,500,000 gallon rate the saving would be $31.69, or 1.26 cents per 1,000 gallons. The increased saving would be due to lower fixed charges per unit of output.

COST OF SOFTENING AT WINNEPEG.

Cost of softening one thousand Imperial gallons when running pumps at 1,510,000 gallon rate, the daily average when plant was installed (capacity of plant, 3,600,000 gallons).

Lime, 3.41 pounds, at $11.00 per ton	1.87 c	
Coke, 0.29 pounds, at $10.00 per ton	.145c	
Acid, 0.034 pounds, at 5½c per pound	.187c	
Total for chemicals	2.202c	2.202c
Filter cloth renewals	0.155c	
Interest at 6% on investment	0.186c	
Depreciation on tanks, etc., at 10%	0.150c	
Power, pumping to softening plant	0.500	
Power for engine running stirrers and washer, steam for lime pump and for heating of building	0.200	
Labor	0.977	
Total, excluding chemicals	2.168	2.168
		4.370c

DEDUCTING POSSIBLE SAVINGS.

(a) Cheaper lime and acid, and saving all coke..	1.16	
(b) Saving in labor and fixed charges when running at 2,500,000 gal. rate..	0.36	
Total saving..		1.52
Net cost when operating at higher rate and with possible savings in effect..		2.85 c

Two and eighty-five hundredth cents per 1,000 Imperial gallons means 2.36 cents per 1,000 U. S. gallons. The present cost of 4.37 cents per 1,000 Imperial gallons means 3.64 cents per 1,000 U. S. gallons. This can be reduced as indicated.

CONCLUSION.

The Winnipeg Softening Plant, the first municipal plant in North America, and one of the two largest ones in the world, has been built for less than the estimate made by Mr. Rudolph Hering, and is being operated for the figure he calculated upon with the necessary addition of the extra cost of good lime. He estimated on the use of the lime of the region about Winnipeg, not being aware of its very low grade.

The plant has been in operation since July, 1901, the trial year having ended in October, 1902. The water is very satisfactory, indeed, to all consumers for both domestic and manufacturing uses.

ILLUSTRATED DESCRIPTION OF SOME FILTER PLANTS AND RESULTS.

BY MORRIS KNOWLES.

Mr. President and Gentlemen of the Engineers' Society of Western Pennsylvania:

Although down on the program and introduced as presenting a formal paper this evening, I regret to state that it has not been opportune to prepare such as would fill the requirements, and thus I have prevailed upon some of my friends to loan me slides of existing filtration works. These slides will show various types of construction, methods of maintenance, and some results obtained. As the hour is late, I feel that you will not care to be kept very long, and therefore will cut out a number which, if there had been ample time, I should have been glad to have shown and described in detail, but as it is, we will take up only a few of the more important ones.

First, there will be thrown upon the screen some slides of the Lawrence, Mass., filter plant, for many of which, other than those owned by the speaker, which were obtained while connected with the plant, we are indebted to Mr. M. F. Collins, Superintendent of the water works.

Next, there will be shown several slides of the Philadelphia filter plants, which have been recently built, and two of which are now in operation; for these we are indebted to Mr. John W. Hill, Chief Engineer, Filtration Bureau, Philadelphia, Pa.

These will be followed by a few slides of the Little Falls, New Jersey, filter plant, which has now been in operation a little over a year; for these we are indebted to Mr. George W. Fuller, Consulting Expert for the East Jersey Water Company.

The concluding slides will show some of the results obtained at Lawrence, Philadelphia, and from the Pittsburg experimental filters.

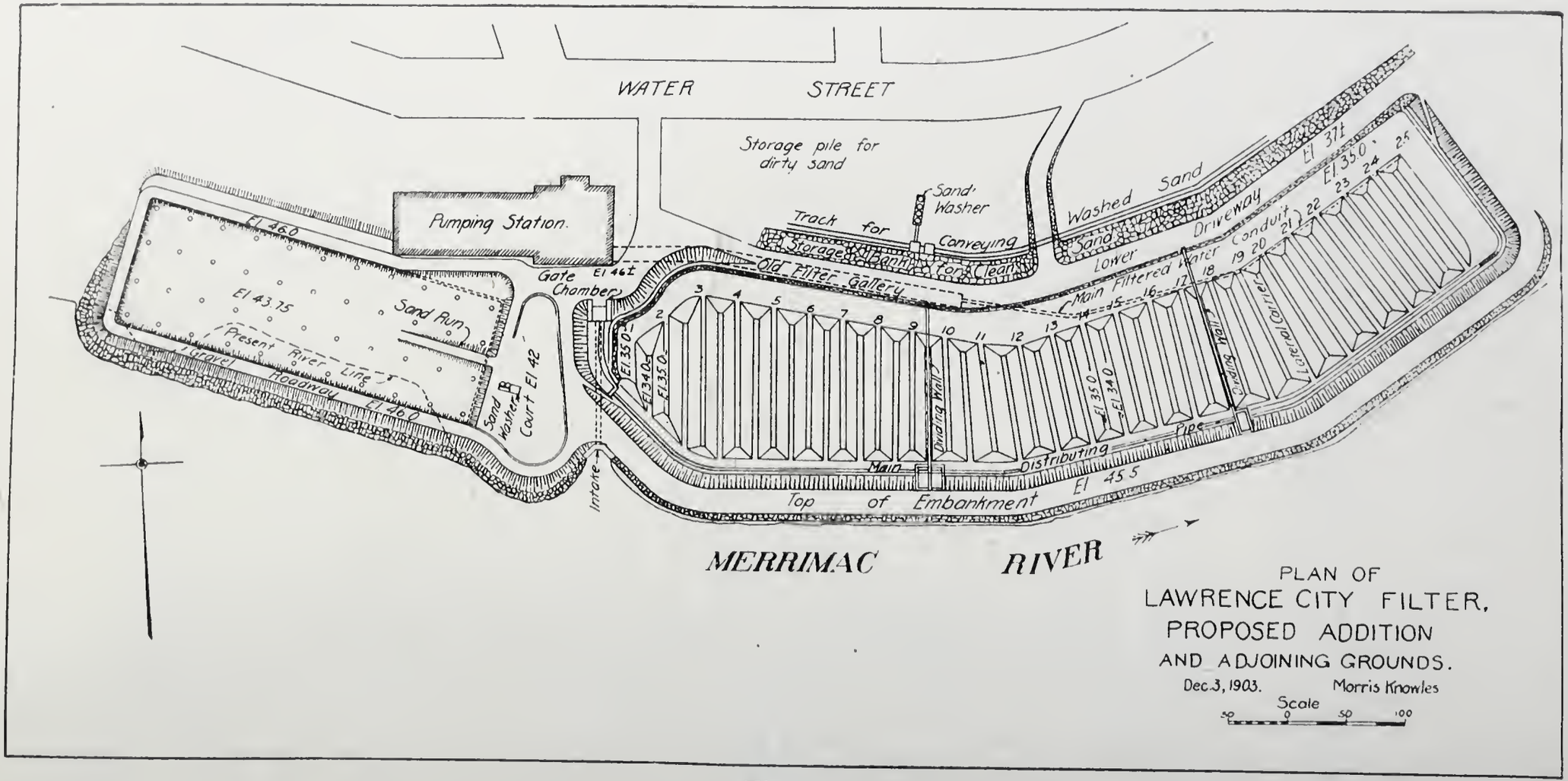

WATER STREET
Storage pile for dirty sand
Pumping Station
Sand Washer
Track for Conveying
Storage Basin for Clean
Washed Sand
Driveway
El 371
El 350
Lower
Main Filtered Water Conduit
Gate Chamber
El 462
Old Filter Gallery
El 460
El 43.75
Sand Run
Present River Line
Tunnel Roadway
El 460
Sand Washer
Court El 42
El 340
El 350
Dividing Wall
Main Distributing Pipe
El 350
El 340
Filtered Water Conduit
Intake
Top of Embankment
El 455
MERRIMAC RIVER
PLAN OF
LAWRENCE CITY FILTER,
PROPOSED ADDITION
AND ADJOINING GROUNDS.
Dec. 3, 1903. Morris Knowles
Scale
50 0 50 100

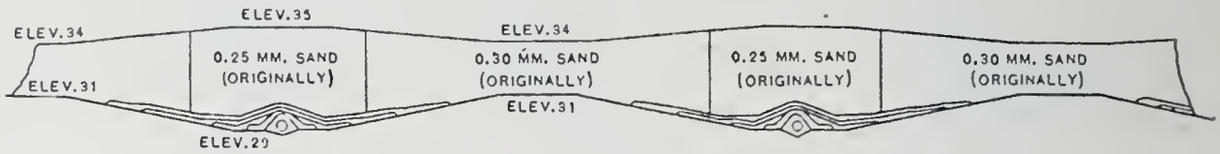
Fig. 1.

LAWRENCE FILTER.

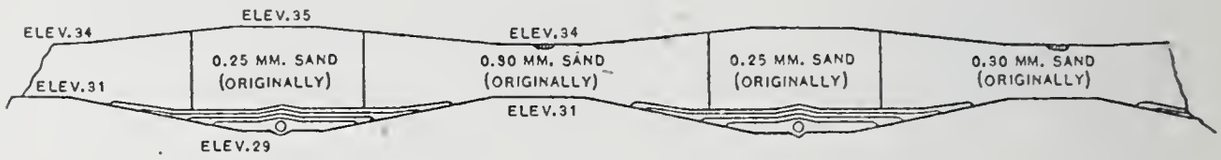
The Lawrence filter (see Fig. 1, General Plan) was built in 1892 and 1893, after the design and under the direction of Mr. Hiram F. Mills, C. E., member of the Massachusetts State Board of Health, and citizen of Lawrence at that time. This filter is about 750 feet long, with an average width of 140 feet, and with a surface area, including the main carrier, of 2.44 acres. The filter surface is divided by transverse carriers into 25 portions or beds, each having an average width of 30 feet. This gives an available filter surface, deducting all carriers, of about 2.3 acres. The filter is uncovered, and is supplied with water from the Merrimac River by gravity. It drains into an old filter gallery, or conduit, along the north side, which empties into the pump well.

The original cost of this filter was $65,000, but additions and improvements have increased this figure to about $90,000. The construction of this filter is unique, in that the surface is undulating and divided into beds by concrete troughs, along which the water flows gradually as the filter is being filled after a scraping. This design was deemed necessary, in order to operate intermittently, so that the air might thoroughly mingle with the water for better purification. In addition, the size of sand directly over and each side of the underdrains was finer, when the filter was originally built, than the body of sand in the intermediate sections. (See Fig. No. 2, Typical Sections.) The thickness and size of the gravel underdrains is also shown on the same sections.

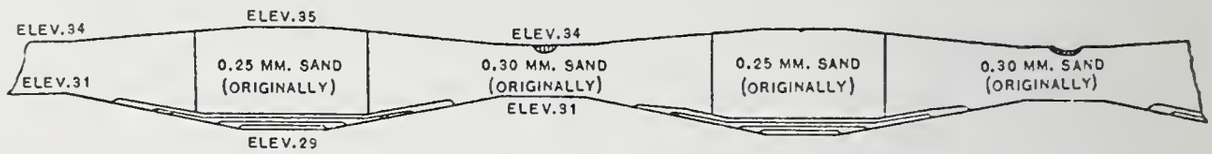
The need of intermittent filtration has not been apparent and, as the demand for water has been almost constantly up to the capacity of the filter, it has been for some time operated in a continuous manner; that is, without periods of rest for the purpose of allowing air to enter into the sand. It is also true that as the sand has been scraped from the surface from time to time and replaced each year, it has come to pass that the distribution of sand in the different sections is no longer maintained, and all is of about the same size. The sand and gravel for this filter were obtained from a large bank deposit, distant about seven-eighths of a mile from the filter. Suitable sizes were obtained by selecting



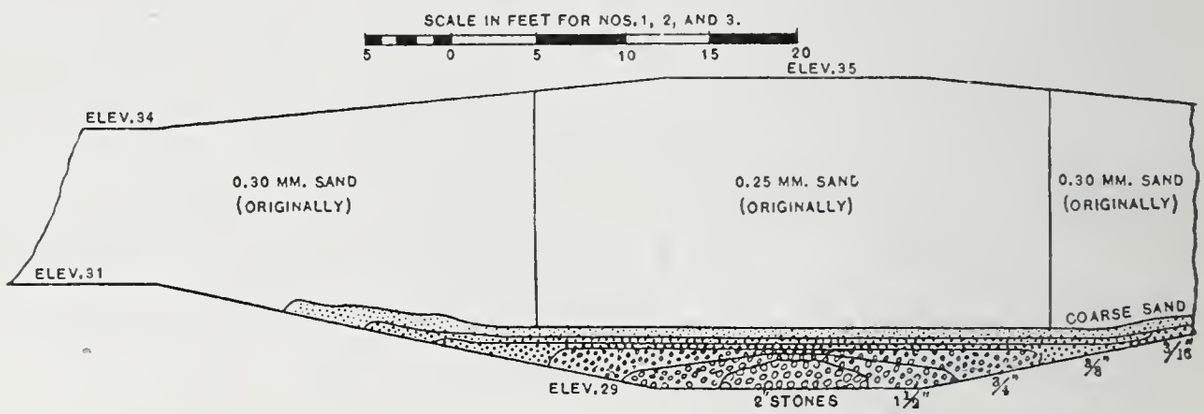
NO.1. CROSS-SECTION AT NORTH END OF BED.



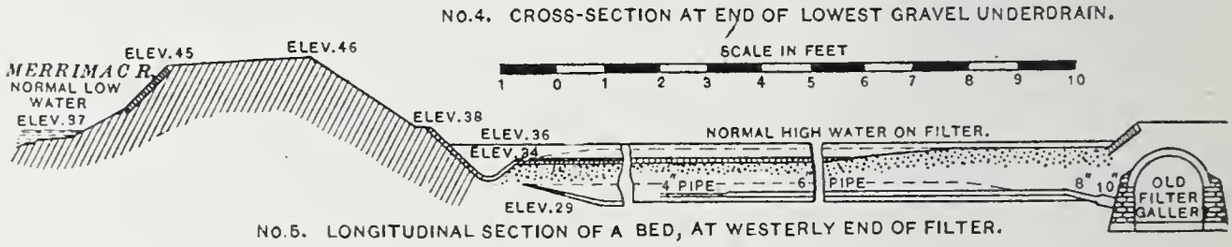
NO.2. CROSS-SECTION AT BEGINNING OF PIPE UNDERDRAIN.



NO.3. CROSS-SECTION AT SOUTH END OF BED.



NO.4. CROSS-SECTION AT END OF LOWEST GRAVEL UNDERDRAIN.



NO.5. LONGITUDINAL SECTION OF A BED, AT WESTERLY END OF FILTER.



TYPICAL SECTIONS OF UNIT BEDS IN LAWRENCE CITY FILTER.

APRIL, 1901

COPIED FROM PLAN FURNISHED BY A. D. MARBLE, CITY ENGINEER.

FIG. 2.

certain layers and pockets and by judicious screening and mixing of the various kinds.

The water is admitted to the filter from the gate house on the westerly end, and passes through the main distribution channel. In 1902 two walls were built across the filter, dividing it into three equal parts, so that one section of the filter can be scraped while the other two are in operation. (See Fig. 3.) They are helpful in saving time and not in allowing the two sections, that are not being scraped, to become filled with entrained air, and also in the winter time operations are facilitated because ice does not become grounded upon these areas. The main distribution channel is now converted into a closed conduit, by means of a cast iron pipe which has openings into the gate chambers at each of the three sections of the filter. The section in the foreground of the picture is in operation, while the middle section is being drained.

The foundations of these division walls are about 1 foot and 9 inches above the bottom of the under drains, and they were built along summits of the ridges of the bottom of the beds, and thus midway between the lateral under drains. The walls are of concrete, 4 feet in thickness at the bottom, stepping up three different times, so that the thickness below the exposed surface of the wall is two feet, eight inches. They are capped with a pointed granite flagging one foot thick. Strange as it may seem from experience with this filter, the bottom of the trench was found to be firm and solid, and a plank was used as a bedding for a short strip only, about 16 feet long, under the most easterly wall.

The water on the surface of the filter is maintained between elevations 36 and 37, giving a depth of from 2 to 3 feet over the low parts of the surface, where the concrete troughs are placed, and from 1 to 2 feet over these portions directly over the under drains, when these summits are at standard grade.

The filter was designed to yield two million gallons per acre daily, which corresponds to the total of about five million gallons for the whole area. Occasionally, however, when certain portions are badly clogged, there are sections which yield a much higher rate and frequently the output is under five million gallons.

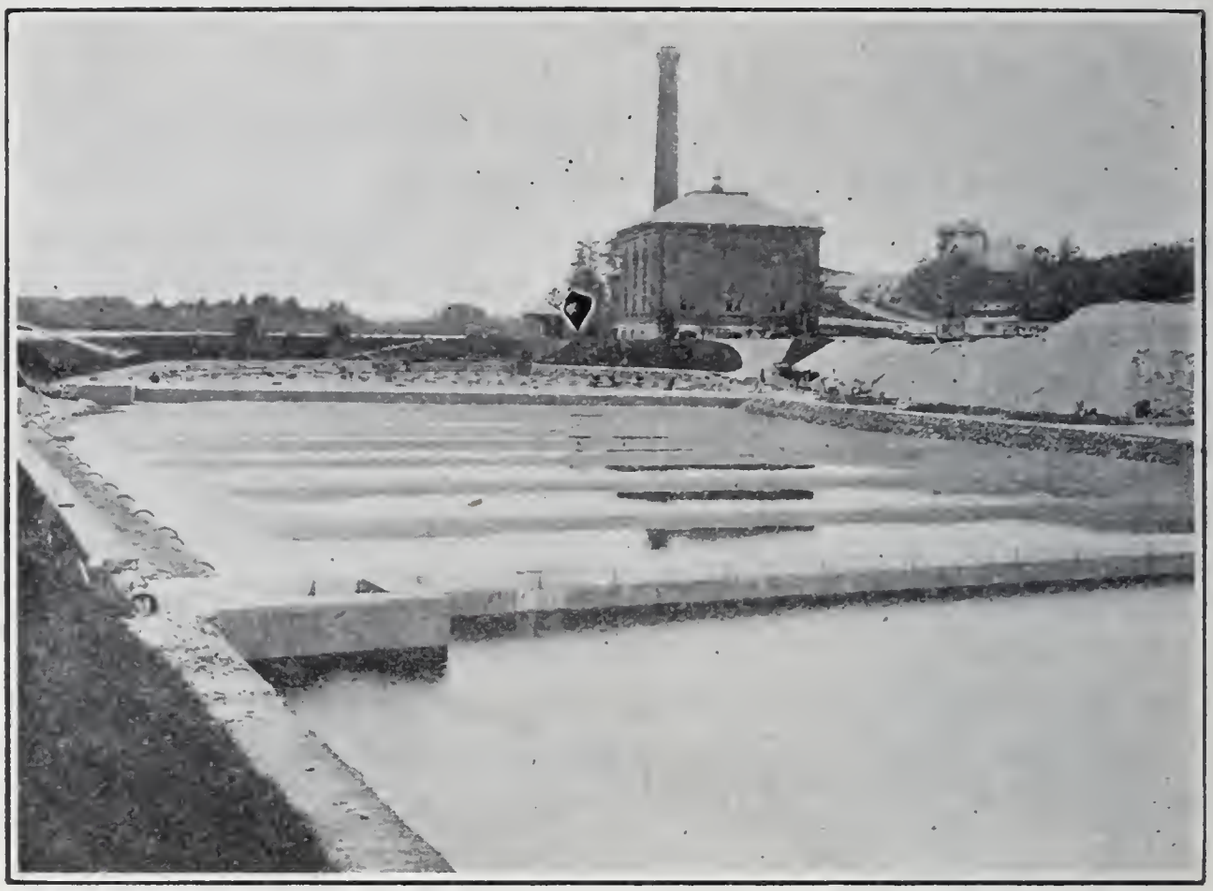


Fig. 3.
Filter at Lawrence, Mass., Showing Division Walls.



Fig. 4.
Scraping Dirty Sand from Filter at Lawrence, Mass.

The operations of the filter maintenance are six in number, and as follows: Scraping, conveying, washing, sanding, removal of snow and ice, and general.

Scraping.—Whenever the yield of the filter is diminished to such a point that not enough water can be obtained, it is known that the surface has become clogged, and it is necessary to scrape. At this time, and generally during the night, the inlet to a certain section of the filter is closed, and, if necessary, when the water will not run away rapidly enough to have the surface clear by morning, an 8-inch centrifugal pump is used, and the surface water pumped back into the river. Thus, on next morning, all is ready to go upon the bed and scrape. This is done by laborers, using shovels of extra width, with long handles and removing the *schmutzdecke*, varying from one-half to one inch in thickness. The sand is thrown into piles a convenient distance apart, as is shown in Fig. 4.

The average number of scrapings for the various 25 beds, as copied from the records, are as follows:

Year.	Number.	Year.	Number.
1895	14	1899	17
1896	12	1900	16
1897	17	1901	12
1898	13	1902	14

Conveying.—This work has been done at Lawrence, as is shown in Fig. 5, by workmen wheeling out in barrows, upon planks laid upon sand surface and depositing the sand along the lower driveway. This is a slow and tedious operation, and is one of the large items of expense in operating this filter. Formerly, also, the sand was hauled from this lower driveway by teams to the dirty pile of sand near the washing machine. This latter, however, is now being done by throwing the sand by an ejector from the lower driveway direct to the washer. This will be more fully shown and explained under the heading of washing. There is no reason why the sand cannot be transferred directly from the piles upon the filter surface to the washing machine, and to the storage pile adjacent, without the intervention of any barrow or team transportation. This latter method is now used at Philadelphia, as will be shown later.



Fig. 5.
Wheeling Dirty Sand from Filter at Lawrence, Mass.



Fig. 6.
Washing Machine and Movable Hopper at Lawrence, Mass.

The cost of scraping by years, which also includes conveying and the smoothing of surface, has been as follows:

Year.	Cost per million gallons.
1896	$2 30
1897	3 67
1898	2 97
1899	3 02
1900	2 93
1901	2 13
1902	2 54

Studies of this whole subject have shown that of the above, conveying costs about one-half, the scraping one-third, and the smoothing one-sixth of the total, which shows very clearly that a less expensive form of conveying will reduce materially the excessive cost of maintenance at Lawrence.

Washing.—The washing machine used at Lawrence is of the ejector type, and is probably the first one of its kind used in the country, the design being similar to some of those used in Europe. The bowls of the machine are four in number, and are sweep castings. (See Fig. 6.) The sand drops to the bottom of each hopper and is caught by an inflowing horizontal jet and carried across and upward through a 3-inch pipe to the next bowl. The pipe fittings for such machines are of standard make. Special fittings for the receiving throat and entrance nozzle, which wear out frequently, are made as required at the shop of the Water Department. The travelling ejector is used for transporting sand to the washer, and is shown in Figure 7; being in service to throw sand from the lower driveway to the first hopper of the washing machine above. It is simply a hopper mounted upon a light frame of piping and fed by a two-inch pipe connection from the main supply,, the sand passing through a three-inch pipe to the washer. In addition to the transportation benefit with the use of ejector, the sand is more thoroughly mingled with the water, in passing through this long line of pipe and thus a more thorough washing occurs and fewer hoppers can be used.

As an indication of the saving in this particular item, when washing operations were first begun in Lawrence, it required 6 men and now 4 men do the entire work of tending machine and taking away the clean sand. As the latter part of the operation

can be handled by water, if proper facilities be introduced, two, or at the most, three men are all that would be necessary. The ordinary water pressure at the machine, with everything running, is 63 pounds; and 56 pounds at the traveling hopper.

A statement of the cost and volume of water used in washing operations at Lawrence is as follows:

Year.	Cost per cubic yard.	Volume of water to sand.
1897	$ .67	14
1898	.62	14
1899	.45	13
1900	.50	10
1901	.48	10
1902	.38	..

The cost of wash water is not included in the above figures.

Sanding.—In this operation the bed is scraped and a depth of ten or twelve inches of sand in a certain section is removed and placed to one side; then such an amount of clean sand is placed in the excavated section as will bring it to grade when the old sand is replaced upon it. The old sand is then brought back and placed over the new material, and the surface shaped and smoothed. Such care is observed in removing old material because even within the few inches of sand below the dirty layer, or *schmutzdecke,* there is a certain amount of clogging sediment, and if the new material should be placed upon this it will cause a subsurface clogging in the filter which will be detrimental to operation, and cause more frequent scrapings. Thus enough old material is removed, so that there is a clean fresh surface on which to place the new sand.

Removal of Snow and Ice.—During the months of December, January, February, and March, scraping can seldom be accomplished without first removing the snow and then the ice from the surface of the filter. In cold weather, when the filter has been drained, an additional thickness of ice will also form directly upon the sand surface, which is troublesome and increases very much the cost of scraping, as it makes handling more difficult, and also the amount of sand to be removed is much greater. In Fig. 8, there is shown a layer of ice, 15 inches in thickness, in direct contact with the sand surface. The piles of sand with mingled



Fig. 7.
Throwing Dirty Sand from Lower Driveway to Washer—Lawrence, Mass.



Fig. 8.
Ice on Filter at Lawrence, Mass., Lowered to Sand Surface when Drained.

ice may also be seen, which shows that the quantity of material to handle is much larger on account of the ice freezing at the sand surface.

The ice is removed by an elevator or conveying machine, after being cut. This cutting is done with a horse ice plow, when the ice is of sufficient thickness. The cakes are cut off with hand chisels and then pushed to the conveyor of the ice machine. (See Fig. 9.)

The ice machine travels along a railway upon the river bank of the filter and throws the ice over into the river. The new machine was placed in operation in the winter of 1901 and 1902, and takes a cake 36 inches square and thus is much more sufficient than the old machine, which would take a cake only 18" x 30". Some idea of the amount of ice which has to be removed can be gathered from Figure No. 10, which shows the large piles of ice along the river bank and corresponds to three day's cutting.

The ice is rarely allowed to become more than 15 inches thick, and generally three or four crops are cut from the filter surface. The cost of removing snow and ice is an expensive operation, and has varied from $1.90 to $2.90 per million gallons, according to the severity of the winter and the methods used. The average cost of removal has been about $1,100 per year per acre of net filter surface. The cost of such removal, because the demands of consumption are such that the filter must be scraped as usual in the winter time, is greater than at places where there is plenty of reserve filter area provided. The average yearly cost per acre, capitalized at 4% is $27,500, a sum much in excess of the necessary cost per acre to erect a cover over the present filter. In fact in any place where it costs more than $600 to $800 per acre to remove the ice and snow in the winter time, it will be found cheaper, even if there were no other reasons, to cover the filters.

Miscellaneous items, not included in the previous classification, come under "General Maintenance," which includes care of lawns, driveways and banks, cleaning channels, and other miscellaneous work.

A tabulation of the costs of maintenance for each year is given in table No. 1.



Fig. 9.
Removing Ice from Filter at Lawrence, Mass.



Fig. 10.
Ice on River Bank at Lawrence, Mass., which has been Removed from Filter.

TABLE NO. 1.

Itemized statement of cost of maintenance of the Lawrence Filter; for the years 1895 to 1902, inclusive.

ITEMS.	1895	1896	1897	1898	1899	1900	1901	1902
Scraping	$2,550	$1,350	$1,950	$1,930	$2,060	$2,130	$1,572	$1,993
Scraping and sanding		1,460	840	300	1,270	1,250	1,007	525
Conveying	1,320	1,180	2,2 0	1,660	1,470	1,410	848	1,185
Washing	1,000	2,120	1,950	1,600	1,450	1,510	972	340
Removal of snow and ice	2,780	2,350	2,330	3,480	2,300	2,330	2,904	3,666
General	450	490	850	710	500	720	566	1,131
Total	$8,100	$8,950	$10,120	$9,680	$9,050	$9,350	$7,869	$8,840
Per million gallons	7.80	8.10	9.00	8.00	7.70	7.70	6.93	7.88
Total minus snow and ice	5,320	6,600	7,790	6,200	6,750	7,020	4,965	5,174
Per million gallons	5.10	6.00	6.90	5.10	5.80	5.80	4.38	4.61
Special repairs	.....	.....	.....	4,830	.....	2,260	1,807	1,090
Total pumpage for year in million gallons	1,040	1,100	1,130	1,210	1,170	1,210	1,134	1,250

New Filter.—The new covered filter, designed by Chapin & Knowles, of Pittsburg, Pa., and Canton, Ohio, the location of which is shown upon Figure 1, will also receive its water from the gate house already built and will be separated from the present filter by a depressed court, of granolithic pavement, to be used for washing and storing of sand.

The filter is 21 bays long by 7 wide, and has a groined arch roof, designed to have 3 feet of earth on top; also, it has an inverted arch floor. The net filtering area will be about three-fourths acre. The vaulting is to have a clear span of 13 feet 2 inches, with a rise of 2 feet 9 inches and be 6 inches thick at the crown and 21 inches thick over the piers. The filter and the court are surrounded by an embankment 10 feet wide at the top and planned with sluice-way openings, so that drainage water will run to the river, but with means for closing, so that the floods of the river will not enter upon the surface.

The underdrain system will consist of a concrete main collector, in the form of an arch, running the whole length of the filter in the center bay. This collector is provided with three manholes, to permit of entrance for cleaning, if the occasion demands. The laterals from this main collector consist of about 15 feet of 12-inch terra cotta channel pipe (or one-half pipe), laid with open joints, reducing to a six-inch, and extending to the center of the outside bay. The gravel is to be 12 inches thick and of graded sizes, and this will be covered with 4½ feet of filter sand. Some of the details of construction can be seen upon Figure 11.

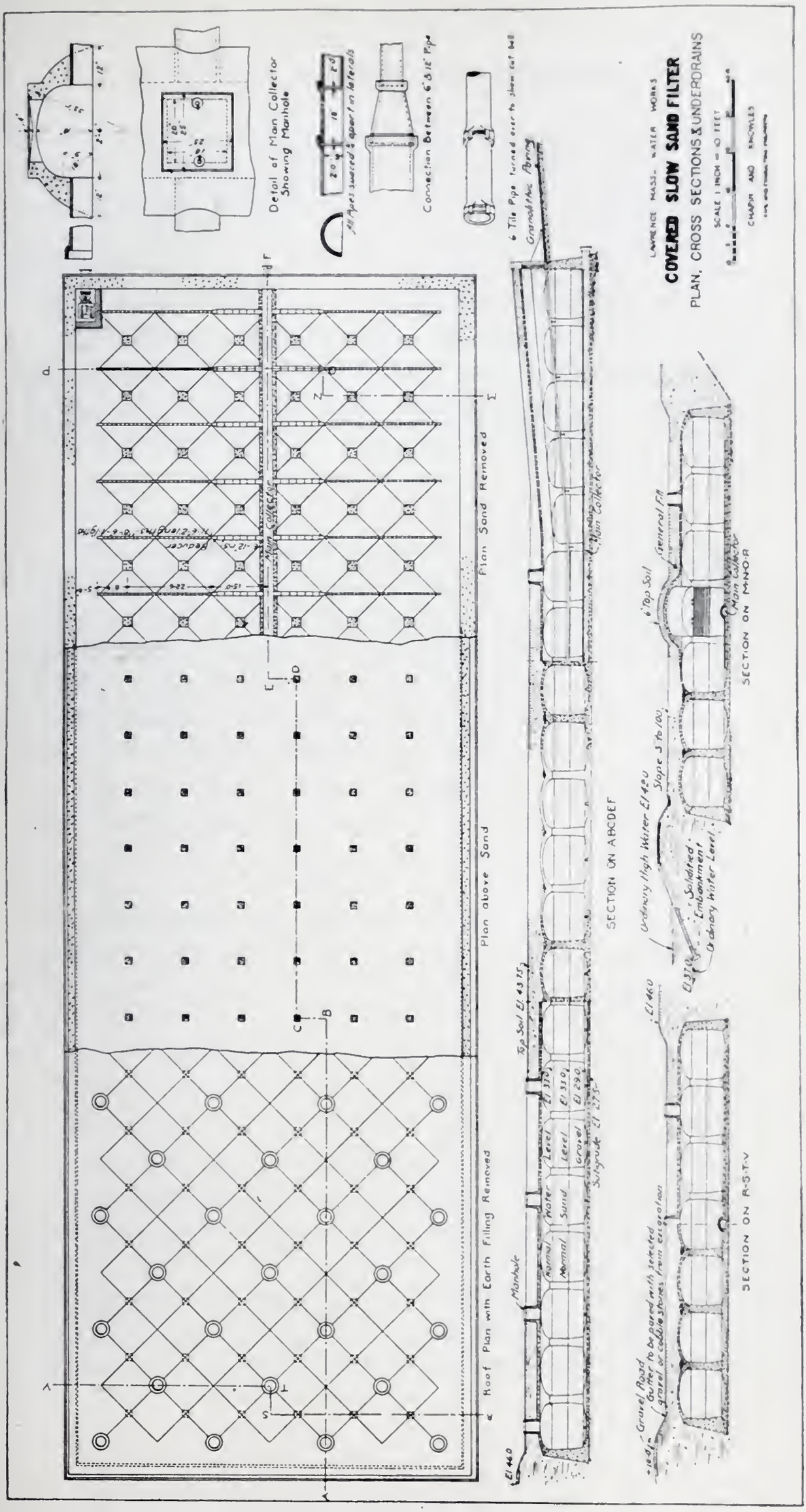

COVERED SLOW SAND FILTER
PLAN, CROSS SECTIONS & UNDERDRAINS
Detail of Main Collector Showing Manhole
All Pipes spaced 6 apart in laterals
Connection Between 6 & 12" Pipe
6" Tile Pipe turned over to show cut bell
Plan Sand Removed
Plan above Sand
Roof Plan with Earth Filling Removed
SECTION ON ABCDEF
SECTION ON M-N-O-P
SECTION ON R-S-T-V
Ordinary High Water El 420
Slope 3 to 100
Top Soil
General Fill
Gravel Road
Manhole
Main Collector
Reducer

Fig. 11.

In the operation of the filter the water will be delivered in the corner nearest the pumping station by a controlling disc valve of special design. Water is then carried in open troughs, made of channel pipe, placed along the side walls of the filter, so that the inflowing water is uniformly distributed over the whole area of the bed, without disturbing the sand. After passing down through the sand, the gravel and the laterals to and through the main collector, the water will run through a 24-inch cast iron pipe to the pump well in the station, where the rate of flow will be regulated by a circular floating orifice, which can be adjusted to the desired rate.

PHILADELPHIA.

Although there had been considerable previous agitation in regard to purification of the water supply of Philadelphia, actual official investigation into the subject took place during the summer months of 1899, by a commission composed of Rudolph Hering, Chairman, Joseph M. Wilson and Samuel M. Gray. After a consideration of various means of purification of the present supplies and also of the feasibility of obtaining purified water from distant and mountain sources, the recommendations of this commission were to provide filtered Schuylkill River water, sufficient to supply West Philadelphia and as much of the westerly and northern portion of the city as can be conveniently done by the capacity of the Schuylkill River, or about 150 million gallons per day of 24 hours; also, to provide for building a filter plant, capable of considerable enlargement, on the Delaware River some distance above the pumping station on that system, from which all of the remainder of the city will be supplied and to which the future additions will be made.

Work upon this system, which was begun in 1900, provides not only for the filtration of, but for the entire reärrangement of the distribution system of the city and the building of the two storage basins of considerable size. Later it is stated that it is intended to meter the services of the city and readjust the water rates to meet the new conditions. This new and comprehensive work in Philadelphia is in charge of Mr. John W. Hill, C. E., Chief Engineer, Filtration Bureau, formerly of Cincinnati, Ohio.

The provisions for filtration at Philadelphia are as follows:

Name of Plant.	Number of Filters. Present.	Ultimate.	Area.	Capacity in million gals. Present.	Ultimate.
Lower Roxborough	5	5	.5 acres	12	12
Upper Roxborough	8	17	.7 "	20	45.5
Belmont	18	26	.73 "	67	97
Torresdale	55	65	.75 "	210	248

The filters at Philadelphia are all of the covered groined arch type, with square supporting columns; all material being concrete.

The underdrains are 16 inches of graded gravel, and on this is placed the filter sand 4 feet in depth. The filters are provided with sand run entrances and have paved courts for the storing and washing of sand.

The entire arrangement, construction and appearance of all of the Philadelphia plants is of the very best and most recent practice, and shows careful and intelligent planning and good results obtained in construction, and the results from the operation bear out and testify to the completeness and accuracy of all of this preliminary work. Great care has been taken in the tightness of all filters and basins, both by the use of puddle underneath and around the concrete, and in some instances by use of asphalt on the concrete lining. So well has this work been done that certain basins show no leakage and the maximum allowable for a three-fourth-acre filter has been placed at 1,000 gallons in 24 hours, which represents about .02 or .03 per cent. of its daily capacity. The Belmont reservoir has had a layer of asphaltic mastic placed on top of the paving concrete. This consists by weight of 70 parts of rock asphalt, 10 parts of Bermudez asphalt, and 20 parts of sharp grit and sand.

Figure No. 12 shows a typical view of filter construction with the floor and columns in plain view. This one is of the Upper Roxborough plant.

Figure No. 13 shows the same filter with part of the roof on and showing the arrangement and method of supporting the arch centres.

Figure No. 14 shows the interior view with the underdrain gravel in place, and shows how it is kept away from the piers. The sand is placed directly upon this gravel and also down to the floor



Fig. 12.
Filter Beds at Upper Roxborough, Philadelphia, Pa., Showing Stages of Floor Construction.



Fig. 13.
Filter Beds at Upper Roxborough, Philadelphia, Pa., Showing Piers and Roof Construction.



Fig. 14.
Interior of Filter, Showing Under-Drain Gravel in Place,
Upper Roxborough, Philadelphia, Pa.



Fig. 15.
General View of Plant After Completion, Lower Roxborough,
Philadelphia, Pa.

near the walls and piers, making a continuous surface over the whole filter. Some filters have been built with gravel extending up to piers and walls.

Figure No. 15 shows the court at Lower Roxborough filter, with the gate or operating houses and sand run entrances on the left of the picture.

The water of the Schuylkill and Delaware Rivers is very muddy, even worse than that of the Allegheny at Pittsburg, and it is believed at Philadelphia that it will be best to treat this water in a preliminary way before passing to the filters, so that they will not be taxed too severely, and too much mud deposited on the surface of the sand. It is decided to give this preliminary treatment, by means of roughing or preliminary filters, which have been tried with $2\frac{1}{2}$ years' experience at the Spring Garden and Delaware Testing Stations, and of which it was the writer's pleasure to have direct charge, during the early history of the development of this problem at Philadelphia. A brief description of these roughing filters as used at the Lower Roxborough Station is that they consist of layers of coarse material, arranged successively from very coarse gravel size at the bottom, to a thicker layer of fine slag at the top, covered with 6″ to 9″ of compressed sponge, pressed down as a mattress on the top of the slag. Crushed slag of various sizes has been found more useful than coke, gravel or broken stone. The water passes from below upward and out from the top of the filter. The water in this way is relieved from a great deal of mud and the life of the sand filter is prolonged and the yield increased. The rates of the preliminary filter, as designed for the Lower Roxborough plant, will vary between 40 and 60 million gallons per acre daily. It is expected that the water will be treated more readily and more economically than could be accomplished with settling basins alone and the use of coagulant with sedimentation at Philadelphia is not in accord with the public sentiment. Frequently this preliminary filter will need to be washed by reversing the current of water and drawing off the mud at the bottom. From four to five times a year the mattress is to be taken out, washed in a machine and the granular material will have to be replaced at certain intervals, not as yet determined, as far as the writer is aware.

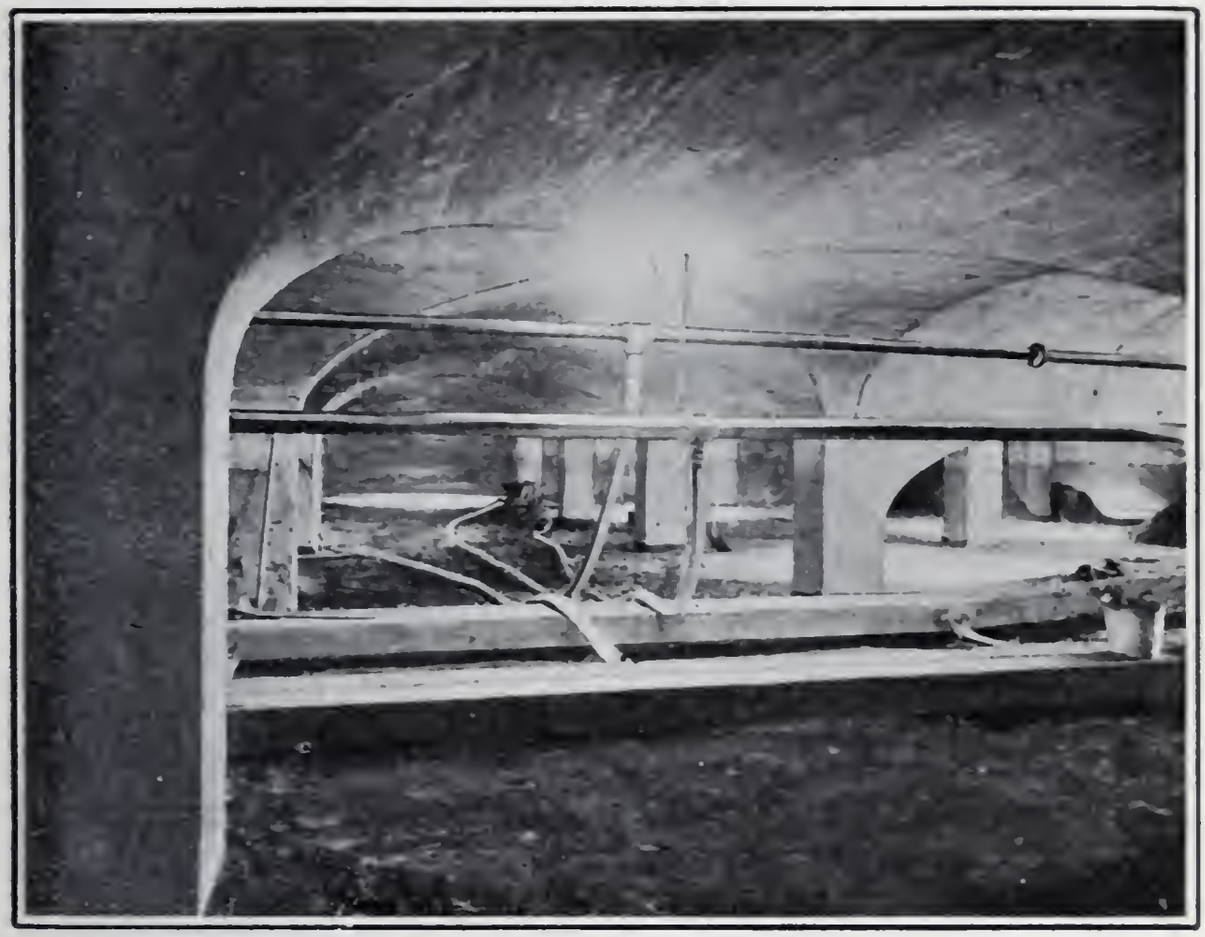


Fig. 16.
Ejecting Dirty Sand from Filter at Upper Roxborough, Philadelphia, Pa.



Fig. 17.
Sand Washing Machine at Upper Roxborough, Philadelphia, Pa.

Operations.—Water was first passed through the Lower Roxborough filters in the fall of 1902; and in the early summer of 1903, the Upper Roxborough plant was started.

The operations at the Philadelphia filter are not very different than elsewhere, except that rapid and marked advances have been made in washing and in the use of conveying the sand by water, when removing sand from the filter and from the washing machine to the clean piles.

Figure 16 shows the hopper in place in the filter, with the inlet water pipe and outlet conveying pipe. One can readily understand from such a picture how the cost of conveying sand, as compared to the laborious wheel barrow method, can be materially lessened by the use of such devices.

Figure 17 shows the point of delivery of the conveying pipe to the washing machine in the foreground. The washed sand is delivered onto the paved court, as is shown by the view in Figure 18.



Fig. 18.
Sand being Stored After Washing at Lower Roxborough, Philadelphia, Pa.

LITTLE FALLS PLANT.

The plant at Little Falls, New Jersey, was built by the East Jersey Water Company, for the purpose of supplying Paterson, Passaic, and numerous other places in the vicinity.

It is, without doubt, the best and most modern representative of a mechanical or rapid system of filtration. The plant is enclosed in a building, a view of which is shown in Fig. 19. The coagulating basin is in the basement of that part of the building at the left of the picture, with various machinery and storage rooms in the floor above. The filters are situate in two wings running from this building side by side. The filter houses are each 140 feet by 30 feet, with an operating platform between the two rows of filters. The clear water basin is placed underneath the filters.

The nominal net capacity of the plant is 32 million gallons daily, and capable, at least for short periods, of yielding 48,000,000 gallons daily. The structures are entirely of concrete, and the entire area occupied is 178 feet by 219 feet. The water flows from the head race above the pumping station into the coagulating basin and then by gravity to the filters. Thence it passes into the clear water basins and from these basins back to the pumping station. All machinery is operated by electric motors and all valves are of the hydraulic type. Figure 20 shows a view of the operating room.

There are 32 filters, which are rectangular in shape. They are cleaned by the current of water passing in an upward direction. The bed is agitated and broken up by the applied water and the use of a pressure of air of about 3 pounds, and at the rate of about 1,000 cubic feet for each filter. About 3% of wash water is used.

This plant was built under the immediate supervision of Mr. W. B. Fuller, Resident Engineer in charge, and Mr. J. Waldo Smith, as Chief Engineer and Superintendent of the East Jersey Water Company. Mr. George W. Fuller, as previously stated, was the Consulting Expert, in regard to the design and equipment of the whole plant. The Water Company assumed the entire responsibility as to the efficiency and behavior of the plant in



Fig. 19.
Filtration Building at Little Falls, N. J.

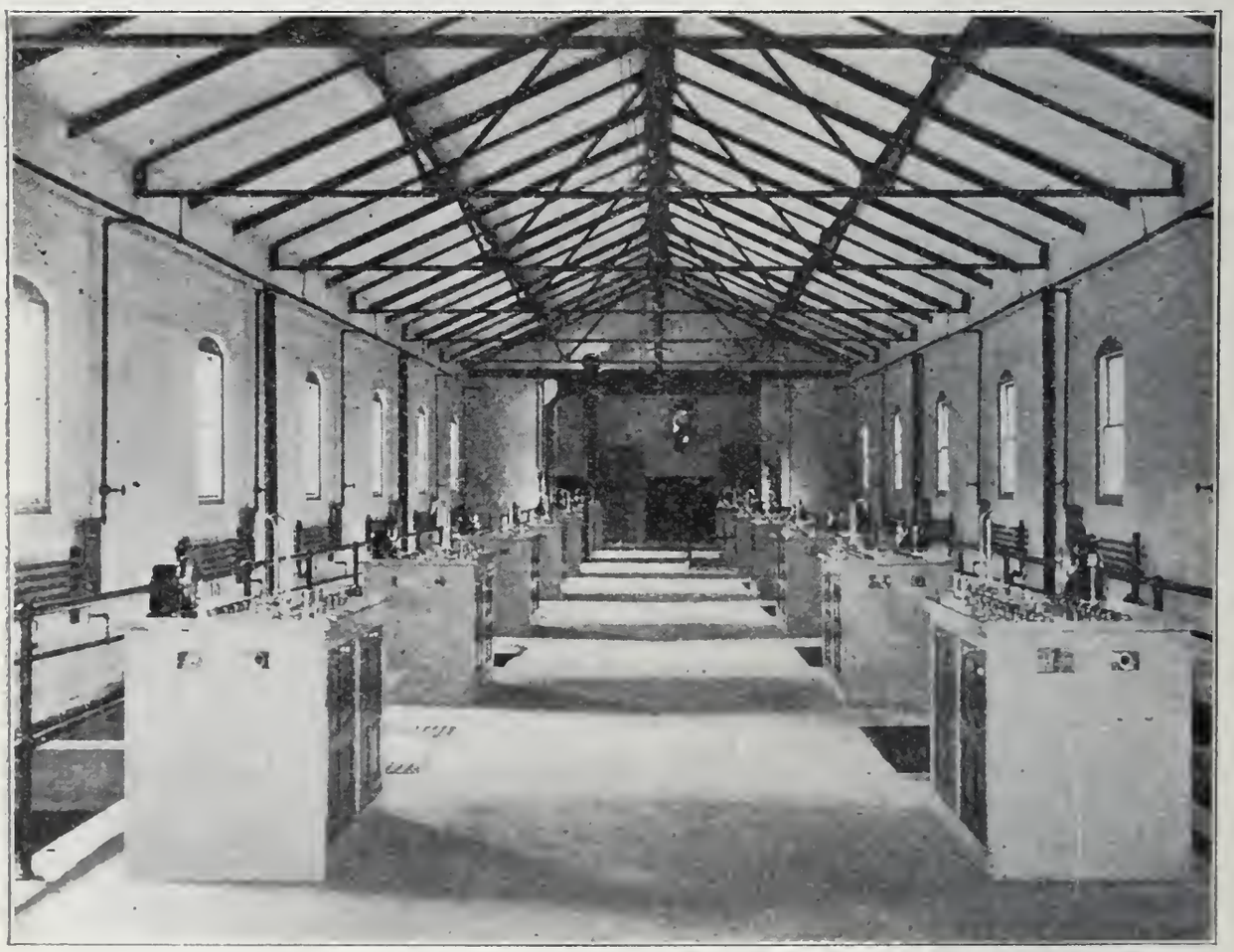


Fig. 20.
Operating Room at Little Falls, N. J.

treating the water, although the physical efficiency of the machinery and several of the mechanical devices were guaranteed by the contractors for the equipment of the filters, the New York-Continental-Jewell Filtration Company. The T. A. Gillespie Company, which is a Pittsburg firm, had the contract for construction of masonry work and buildings. Work was begun in April, 1901, and the plant was placed in operation in September, 1902.

FILTRATION RESULTS.

This seems to be a good opportunity to complete the history of the Pittsburg Experimental filters down to January, 1901, so that the results previously obtained by the Pittsburg Filtration Commission can be compared to those of later periods down to the time when the plant was actually put out of service; the whole data will thus be placed in convenient form for reference. We are indebted for these latter results to Mr. E. M. Bigelow, Director Department of Public Works, and Mr. A. B. Shepherd, Superintendent of the Bureau of Water, under whose direction these filters have been operated since 1899.

Tables Nos. 2, 3 and 4 give the results as shown by monthly averages for the whole time. Tables Nos. 5, 6 and 7 give the average results arranged by periods; that is, taking the individual runs between each scraping. Various notes and explanations are made, and in addition some explanations are given here. In June, 1899, sand was added of a size somewhat smaller than was previously used; thus, the periods between scrapings were shorter than before. It will be noticed that two settling basins were used after August, 1899, which caused the water applied to Filter No. 2, to travel in a tortuous course, horizontally, and thus gave a more complete displacement.

During the autumn and winter of 1898, sulphate of alumina was added to the applied water as it entered the settling basin, at rates varying from one quarter of a grain to one grain per gallon. Asbestos fibre was also used on the surface of one of the filters. Neither of these special experiments was productive of conclusive evidence, as the time of trial was limited, but the facts are recorded here, so that the history may be complete. Prob-

TABLE NO. 2.

PITTSBURGH EXPERIMENTAL SAND FILTERS.

AVERAGE OF DAILY RESULTS BY MONTHS, DURING 1897–8.

MONTHS.	Hours in Operation Per Day.		Rate of Filtration Million Gallons Per Acre Daily.		Turbidity. Platinum Wire Method.		Turbidity. Silver Nitrate Method. Effluents.		Bacteria Per Cubic Centimeter. Raw Water.	Settled Water.	Effluents.		Percentage of Bacteria Removed.	
	No. 1.	No. 2.	No. 1.	No. 2.	Raw Water.	Settled Water.	No. 1.	No. 2.			No. 1.	No. 2.	No. 1.	No. 2.
1897.														
August	23.8	22.9	2.40	2.30	0.18	0.13	.....	.....	2090	1280	46	42	97.80	97.99
September	24.0	24.0	2.98	3.00	0.05	0.04	.....	.....	2480	1230	16	16	99.35	99.35
October	23.3	23.7	2.90	2.95	0.03	0.03	.....	.....	72900	39200	32	32	99.96	99.96
November	21.5	20.1	2.64	2.42	0.26	0.18	.....	.....	25200	29900	346	632	98.63	97.49
December	22.4	23.5	2.76	2.46	0.19	0.14	.....	.....	14400	14900	163	225	98.87	98.44
Average, 1897	23.0	22.8	2.74	2.63	0.14	0.10	.....	.....	23410	17300	121	189	98.92	98.65
1898.														
January	22.5	22.8	2.77	1.87	0.27	0.15	.....	.....	15300	13800	334	310	97.82	97.98
February	23.5	23.4	2.93	2.27	0.15	0.10	0.011	0.011	9430	12000	266	275	97.18	97.08
March	23.5	22.7	2.95	2.83	0.28	0.17	0.013	0.017	11700	12300	71	332	99.40	97.17
April	23.4	23.5	2.95	2.99	0.08	0.08	0.003	0.005	5010	4930	33	91	99.34	98.18
May	23.6	23.6	2.93	2.95	0.19	0.12	0.012	0.011	10800	6770	110	99	98.98	99.08
June	22.8	22.9	2.83	2.85	0.19	0.11	0.011	0.012	11100	5930	135	72	98.78	99.35
July	23.5	23.6	2.94	4.97	0.11	0.07	0.003	0.003	16800	13000	74	89	99.56	99.47
August	22.8	23.1	2.85	4.82	0.36	0.25	0.008	0.017	15100	10250	51	82	99.66	99.46
Average, 13 months	23.1	23.1	2.83	2.98	0.18	0.12	.....	.....	16400	12800	128	176	99.22	98.93
1898.														
September	23.4	22.1	3.04	4.67	0.04	0.03	0.004	0.006	18100	17500	54	120	99.70	99.34
October	23.8	21.9	2.90	4.62	0.11	0.09	0.003	0.003	35200	34600	100	140	99.72	99.60
November	23.7	20.7	3.09	2.61	0.10	0.10	0.010	0.009	15700	12000	190	325	98.79	97.93
December	22.0	22.7	2.85	2.73	0.11	0.08	0.005	0.006	22400	19400	940	850	95.80	96.21
Average, 1898	2.23	22.7	2.92	3.35	0.17	0.11	0.008	0.009	15700	13600	197	233	98.75	98.58

TABLE NO. 3.

PITTSBURGH EXPERIMENTAL SAND FILTERS.

AVERAGE OF DAILY RESULTS BY MONTHS, DURING 1899.

MONTHS.	Hours in Operation Per Day.		Rate of Filtration Million Gallons Per Acre Daily.		Turbidity. Platinum Wire Method.		Turbidity. Silver Nitrate Method. Effluents.		Bacteria Per Cubic Centimeter. Raw Water.	Settled Water.	Effluents.		Percentage of Bacteria Removed.	
	No. 1.	No. 2.	No. 1.	No. 2.	Raw Water.	Settled Water.	No. 1.	No. 2.			No. 1.	No. 2.	No. 1.	No. 2.
January.....	24.0	23.3	3.06	3.01	0.15	0.13	.016	.012	29700	38300	506	360	98.30	98.79
February.....	22.4	23.4	2.97	3.10	0.15	0.10	.008	.007	12600	16200	380	340	96.99	97.31
March	23.3	23.4	3.15	2.95	0.21	0.18	.021	.021	17400	16800	179	282	98.97	98.38
April.....	23.3	23.3	3.17	3.08	0 10	0.09	.016	.012	7000	7110	65	64	99.07	99.09
May	22.4	23.5	2.99	3.12	0.14	0.13	.008	.012	10000	9810	114	128	98.86	98.72
June, 6 days	23 2	24 0	3.07	3.12	0.18	0.09	.012	.010	5730	3840	79	106	98.62	98.15
June, 19 days	24.0	23.9	2.02	2.00	0.16	0.13	.016	.016	13600	4900	1500	1010	89.00	92.60
July	22.2	22.8	2.40	2.44	0.20	0.18	.011	.015	8250	4640	218	128	97.36	98.45
August.....	23.2	23.4	2.92	2.89	0.27	* 0.24 / 0.17	.015	.016	20400	* 14900 / 18700	56	86	99.73	99.58
September...	23.2	23.2	2.93	2.94	0.16	* 0.15 / 0.13	.010	.009	23600	* 15800 / 16100	56	44	99.76	99.81
October	23.2	23.3	2.97	2.97	0.04	* 0.04 / 0.04	.002	.002	41500	* 29900 / 26500	48	45	99.88	99.89
November...	21.7	21.7	2.68	2.64	0.15	* 0.14 / 0.13	.006	.005	13500	* 10900 / 16200	405	79	97.00	99.41
December ...	23.0	22.6	2.64	2.79	0.18	* 0.17 / 0.14	.012	.013	15000	* 13300 / 12400	121	165	99.19	98.90
Average...	23.0	23.1	2.84	2.85	0 16	0.13	.012	.012	17600	15400	272	207	98.45	98.82

NOTES:—Settled water was applied to both filters all the time, except for occasional days.

Averages of both periods in June, and, for records starred, the average of both results, were used in computing yearly averages.

*First results given where starred refers to water applied to Filter No. 1, and second results to that applied to Filter No. 2.

TABLE NO. 4.

PITTSBURGH EXPERIMENTAL SAND FILTERS.

AVERAGE OF DAILY RESULTS BY MONTHS, DURING 1900.

MONTHS.	Hours in Operation Per Day.		Rate of Filtration, Million Gallons Per Acre Daily.		Turbidity. Platinum Wire Method. Raw Water.	Settled Water. No. 1.	Settled Water. No. 2.	Silver Nitrate Method. Effluents. No. 1.	Effluents. No. 2.	Bacteria Per Cubic Centimeter. Raw Water.	Settled Water. No. 1.	Settled Water. No. 2.	Effluents. No. 1.	Effluents. No. 2.	Percentage of Bacteria Removed. No. 1.	No. 2.
	No. 1.	No. 2.	No. 1.	No. 2.												
January ...	21.1	21.1	2.45	2.34	0.19	0.14	0.13	.012	.014	22100	28000	22800	463	535	97.90	97.58
February ..	21.7	23.1	2.69	2.91	0.20	0.17	0.16	.020	.020	30500	28900	34200	495	415	98.38	98.64
March	20.9	22.6	2.62	2.69	0.21	0 18	0.15	.018	.018	21500	19500	17300	204	157	99.05	99.27
April	23.2	22.5	3.03	2.83	0.07	0.06	0.05	.010	.006	7400	10200	9300	38	74	99.49	99.00
May.....	22.5	22.6	2 91	2.88	0.03	0.03	0.03	.009	.008	5800	4000	3000	45	41	99.22	99.29
June	22.6	22.7	2.93	2.79	0.19	0.18	0.18	.005	.003	9000	6700	6100	43	116	99.52	98.71
July	22.3	22.7	2 75	2.75	0.40	0.33	0.23	.002	.002	13200	10400	9400	37	59	99.72	99.55
August.....	22.6	23.4	2.85	2.96	0.15	0.14	0.12	.000	.000	15200	16500	12800	70	30	99.54	99.80
Septembe .	22.6	22.6	2.88	2.94	0.09	0.09	0.07	.001	.001	28800	27100	22300	32	54	99.89	99.81
October.....	23.3	23.3	3.10	2.96	0.08	0.07	0.07	.002	.001	77400	73100	72000	114	97	99.85	99 87
November.	21.8	21.9	2.75	2.63	0.20	0.18	0.16	.008	.008	28200	34500	31600	392	505	98.61	98 21
Decemb r..	22.0	22.7	2.48	0.99	0.07	0.05	0.06	.010	.007	9200	12100	11200	274	99	97.02	98.92
Averages	22.2	22.6	2 80	2.64	0.16	0.13	0.12	.008	.007	22400	22600	21000	184	182	99.02	99.05

TABLE NO. 5.

PITTSBURGH EXPERIMENTAL SAND FILTERS.

QUANTITATIVE RESULTS OBTAINED DURING EACH PERIOD OF OPERATION WITH THE SAND FILTERS, THE LOSS OF HEAD BEING LIMITED TO FOUR FEET—DURING 1897-8.

Number of Period.		Date of Beginning.		Number of Days.		Average Turbidity. Platinum Wire Method. Applied Water.		Silver Nitrate Method. Effluent.		Quantity Filtered, Million Gallons per Acre.		Depth of Sand in Feet, Removed at Scraping.	
No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.
1897	1897												
1	.....	July 24, 1897.....	.....	22.8	.....	0.19	.....	.....	.....	44.6	.....	0.04	.....
2	2	Aug. 18, 1897 ...	Aug. 4, 1897	45.7	14.7	0.06	0.27	.....	.....	135.9	30.8	0.06	0.04
3	3	Oct. 11, 1897.....	Aug. 21, 1897 ...	32.9	37.1	0.03	0.06	.....	.....	98.8	111.3	0.05	0.04
4	4	Nov. 18, 1897	Oct. 2, 1897.....	17.9	37.0	0.20	0.04	.....	.....	53.1	111.8	0.05	0.06
5	5	Dec. 9, 1897	Nov. 18, 1897 ...	18.2	4.2	0.15	0.54	.....	.....	54.1	12.1	0 13	0.07
.....	6	.....	Nov. 25, 1897 ...	.....	11.0	.....	0.24	.....	.....	.....	32.7	.....	0.09
.....	7	....	Dec. 11, 1897 ...	.....	21.4	.....	0.16	.....	.....	.....	51.0	.....	0.05
Average 1897.....		.....	.....	27.5	20.9	0.13	0.22	.....	.....	75.3	58.3	0.07	0.06
1898	1898												
6	8	Dec. 30, 1897.....	Jan. 3, 1898.....	12.1	17.0	0.07	0.18	.....	.....	36.0	34.1	0.03	0.04
7	9	Jan. 12, 1898.....	Jan. 21, 1898.....	12.1	9.4	0.21	0.14	.....	0.022	35.9	18.6	0.05	0.10
8	10	Jan. 27, 1898.....	Feb. 1, 1898	11.2	29.1	0.10	0.10	0.012	0.011	33.1	69.1	0.10	0.06
9	11	Feb. 8, 1898	March 3, 1898...	30.5	18.6	0.10	0.13	0.012	0.009	91.3	56.8	0.07	0.06
10	12	March 11, 1898..	March 23, 1898..	26.4	4.2	0.21	0.98	0.014	0 046	79.8	12.3	0.12	0.13
11	13	April 7, 1898.....	March 29, 1898..	32.8	14.4	0.06	0.14	0.002	0.013	99.2	43.8	0.07	0.07
12	14	May 12, 1898.....	April 13, 1898...	33.3	26.4	0.10	0.08	0.014	0.002	100.2	81.1	0.07	0.07
13	15	June 17, 1898 ...	May 11, 1898 ...	30.0	23.8	0.12	0.21	0.007	0.015	90.4	72.1	0.09	0.10
14	16	Ju y 19, 1898.....	June 5, 1898	30.8	16.1	0.21	0.22	0.003	0.008	92.8	48.4	0.13	0.11
15	17	Aug. 20, 1898 ...	June 22, 1898 ...	.....	17.2	.....	0.15	.....	0.013	.....	69.3	.....	0.06
16	18	Aug. 25, 1898 ..	July 10, 1898 ...	29.8	22.5	0.05	0.07	0.006	0.001	72.3	114.4	0.05	0.07
17	19	Sept. 25, 1898...	Aug. 3, 1898	30.6	17.7	0.06	0.28	0.001	0.012	71.7	89.5	0.09	0.12
18	20	Oct. 29. 1898.....	Aug. 22, 1898 ...	19.8	22.3	0.10	0.09	0.014	0.018	64.0	112.3	0.07	0.09
19	21	Nov. 20, 1898 ...	Sept. 15, 1898...	10.2	33.8	0.05	0.03	0.004	0.002	33.9	179.1	0.10	0.09
20	27	Dec. 2. 1898.....	Nov. 23, 1898 ...	16.2	13.4	0.04	0.04	0.000	0.000	51.2	41.6	0.09	0.24
21	28	Dec. 21, 1898.....	Dec. 9, 1898.....	9.9	13.4	0.20	0.09	0.016	0.002	30.7	41.2	0.15	0.09
Average 1898.....		.....	.....	22.4	18.7	0.11	0.18	0.008	0.012	65.5	67.7	0.09	0.09
V.Aug.,'97--Aug.,'98		.....	.....	25.5	19.0	0.13	0.22	0.009	0.014	74.7	58.8	0.08	0.07

TABLE NO. 6.

PITTSBURGH EXPERIMENTAL SAND FILTERS.

QUANTITATIVE RESULTS OBTAINED DURING EACH PERIOD OF OPERATION WITH THE SAND FILTERS, THE LOSS OF HEAD BEING LIMITED TO FOUR FEET—DURING 1899.

Number of Period.		Date of Beginning.		Number of Days.		Average Turbidity. Platinum Wire Method. Applied Water.		Silver Nitrate Method. Effluent.		Quantity Filtered, Million Gallons per Acre.		Depth of Sand in Feet, Removed at Scraping.	
No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.
22	29	Dec. 31, 1898.....	Dec. 25, 1898.....	34.1	28.1	0.12	0.14	0.013	0.014	100.6	86.6	0.11	0.17
23	30	Feb. 6, 1899.....	Jan. 23, 1899	12.3	27.3	0.05	0.06	0.005	0.006	39.4	84.1	0.09	0.08
24	31	Feb. 22	Feb. 20	30.1	30.2	0.20	0.21	0.022	0.019	96.3	94.0	0.24	0.12
25	32	March 25	March 23	31.3	36.1	0.11	0.12	0.020	0.016	98.5	109.7	0.09	0.06
26	33	April 27.....	April 29.....	23.2	38.2	0 04	0.10	0.005	0.011	76.3	121.8	0.04	0.06
27	34	May 22	June 19.....	15.0	19.1	0.11	0.16	0.011	0.015	18.4	37.8	0.04	0.06
28	35	June 19.....	July 10	19.4	18.0	0.16	0.17	0.012	0.016	38.3	48.9	0.05	0.08
29	36	July 11	July 29	17.0	23.0	0.14	0.23	0.012	0.019	48.0	73.7	0.19	0.08
30	37	July 30	Aug. 23	23.0	28.0	0.21	0.12	0.016	0.010	70.1	82.6	0.06	0.10
31	38	Aug. 24.....	Sept. 22	23.0	36.5	0.22	0.05	0.012	0.003	69.7	107.4	0.11	0.04
32	39	Sept. 17.....	Oct. 29.....	38.0	6.0	0.06	0.13	0 004	0.001	118.2	20.9	0.06	0.02
33	40	Oct. 26.....	Nov. 7.....	10.0	10.0	0.12	0.09	0.002	0.004	29.4	30.6	0.03	0.05
34	41	Nov. 8.....	Nov. 18.....	9.6	11.0	0.09	0.12	0.007	0.007	31.0	32.5	0.05	0.05
35	42	Nov. 19.....	Nov. 30..... ..	9.0	10.5	0.13	0.06	0.007	0.008	26.4	26.4	0.04	0.04
36	43	Nov. 29.....	Dec. 12	8.2	3.5	0.06	0.33	0.008	0.017	23.0	9.5	0.03	0.04
37	44	Dec. 9	Dec. 19	5.2	10.7	0 25	0.15	0.007	0.016	14.3	31.2	0.08	0.09
38	.....	Dec. 16	....	9.1	.....	0.21	.....	0.019	... .	27.7	.....	0.04	....
Averages...		....	....	23.0	26.8	0.14	0.14	0.013	0.013	66.8	79.8	0.09	0.09

NOTE:—Periods 33 to 37 for Filter No. 1 and 39 to 43 for Filter No. 2 were not used in computing averages. Small depths of sand were removed at scrapings, which caused an initial loss of head greater than one foot, and decreased the lengths of the periods.

TABLE No. 7.

PITTSBURGH EXPERIMENTAL SAND FILTERS.

QUANTITATIVE RESULTS OBTAINED DURING EACH PERIOD OF OPERATION WITH THE SAND FILTERS THE LOSS OF HEAD BEING LIMITED TO FOUR FEET—DURING 1900.

Number of Period.		Date of Beginning.		Number of Days.		Average Turbidity. Platinum Wire Method. Applied Water.		Silver Nitrate Method. Effluent.		Quantity Filtered, Million Gallons Per Acre.		Depth of Sand in Feet, Removed at Scraping.	
No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1	No. 2.
39	45	Jan. 6, 1900	Jan. 7, 1900	4.9	3.0	0.03	0.02	0.005	0.004	15.8	10.0	0.05	0.06
40	46	Jan. 13	Jan. 12	7.1	6.4	0.21	0.17	0.016	0.015	22.4	19.2	0.10	0.06
41	47	Jan. 23	Jan. 20	9.3	2.4	0.17	0.42	0.018	0.021	27.8	7.1	0.11	0.14
42	48	Feb. 4	Jan. 25	7.0	12.1	0.21	0.08	0.016	0.015	21.3	36.7	0.06	0.07
43	49	Feb. 13	Feb. 8	10.8	.....	0.15	0.20	0.022	0.023	33.7	.....	0.07	0.10
44	50	Feb. 25	March 2	9.0	14.7	0.24	0.22	0.024	0.018	27.8	42.4	0.11	0.11
45	.....	March 9	.....	8.3	.....	0.14	.....	0.015	.....	25.5	.....	0.05	.....
46	51	March 20	March 21	5.4	19.5	0.23	0.09	0.014	0.013	16.8	59.4	0.05	0.11
47	52	March 27	April 11	18.2	13.0	0.07	0.06	0.014	0.007	57.1	39.2	0.09	0.05
48	53	April 17	April 25	15.3	14.6	0.06	0.04	0.008	0.007	48.2	44.8	0.06	0.05
49	54	May 5	May 11	16.8	19.7	0.03	0.03	0.009	0.007	52.7	60.9	0.05	0.05
50	55	May 24	June 1	14.8	5.0	0.15	0.34	0.006	0.004	46.5	15.2	0.09	0.03
51	56	June 10	June 9	12.4	13.6	0.15	0.14	0.005	0.004	39.0	42.1	0.09	0.03
52	.....	June 24	.....	12.3	.....	0.20	.....	0.003	.....	38.9	.....	0.08	.....
53	57	July 10	June 26	10.0	11.9	0.35	0.25	0.004	0.002	31.5	35.8	0.13	0.09
54	58	July 22	July 11	11.0	11.1	0.21	0.20	0.001	0.003	34.5	33.8	0.07	0.10
55	59	Aug. 4	July 27	14.0	17.2	0.08	0.10	0.000	0.001	44.8	53.0	0.07	0.08
56	60	Aug. 22	Aug. 15	14.2	16.8	0.23	0.17	0.001	0.000	45.2	52.0	0.07	0.07
57	61	Sept. 8	Sept. 2	14.0	15.0	0.08	0.07	0.000	0.001	44.9	46.8	0.08	0.06
58	62	Sept. 26	Sept. 19	22.9	24.8	0.06	0.06	0.000	0.000	74.1	77.5	0.05	0.04
59	.....	Oct. 21	.....	18.6	.....	0.09	.....	0.004	.....	59.7	.....	0.08	.....
60	63	Nov. 11	Oct. 17	7.1	23.7	0.05	0.08	0.005	0.002	22.7	74.1	0.04	0.07
61	64	Nov. 21	Nov. 14	6.0	7.4	0.34	0.05	0.012	0.005	18.9	21.7	0.08	0.06
62	.....	Nov. 29	.....	4.9	.....	0.10	.....	0.016	.....	14.7	.....	0.12	.....
63	65	Dec. 5	Nov. 22	11.7	6 0	0.08	0.45	0.012	0.016	34.7	18.6	0.11	0.07
64	66	Dec. 19	Dec. 2	8.1	21.5	0.04	0 07	0.008	0.007	21.5	22.5	0.03	0.06
Averages...		.....	.....	11.3	13.4	0.15	0.15	0.009	0.008	35.6	38.7	0.08	0.07
1901													
65	67	Dec. 29, 1900	Dec. 28, 1900	9.0	12.3	0.03	0.03	0.009	0.008	22.2	14.4	0.04	0.06
66	68	Jan. 16, 1901	Jan. 17, 1901	17.1	.....	0.06	.....	.....	.....	30.9	.....	.....	.....

ably with complete devices, the reduction of mud in the applied water by use of a coagulant would facilitate the filtration of the same water, provided all traces of coagulation be removed before applying the water to the filters.

In regard to use of asbestos, experiments under the writer's direction have shown that this is a doubtful help, and generally the aid sought by such artificial *schmutzdecke* can be best obtained by other and less expensive methods. It will be noticed that for some of the periods, viz., when the tests with asbestos were conducted, and when, for experimental purposes, very small depths of sand were removed at a scraping, which created a large initial loss of head for the next run, the results are omitted from the tables.

Experiments to determine the effect of mine drainage upon sand filters in this locality were undertaken during the summer of 1900. Without going into the details of the results, it may be stated in general that acid or mine water, on account of the precipitate and deposit of iron in the upper parts of the sand, will shorten the time between scrapings, and thus reduce the quantity of water filtered during periods. The hardness of the effluent will be increased somewhat, but not all of the lime will be taken out of the sand and during seasons following acid or mine water there will be opportunity to replace this lime in the filter sand. If the periods of such mine water are not too long, or occur too frequently, it may be considered as not doing any permanent harm to the beds and not rendering the water unfit for use. In fact, the effluent was very clear and sparlking, and if such water could be obtained during periods when the river is very high and muddy, it could be used with advantage to precipitate out the sediment and color, and the turbidity of the effluent would be very much improved.

In tables showing the results of turbidity, it appears that there is some relation between the length of period, or quantity of water filtered between scrapings, and the average turbidity of the applied water for the period. In other words, as a general statement it may be accepted that the more turbid the water, the less the quantity filtered. This relation, however, is not an exact one, and it is largely due to the fact that the method of obtaining turbidity, while be-

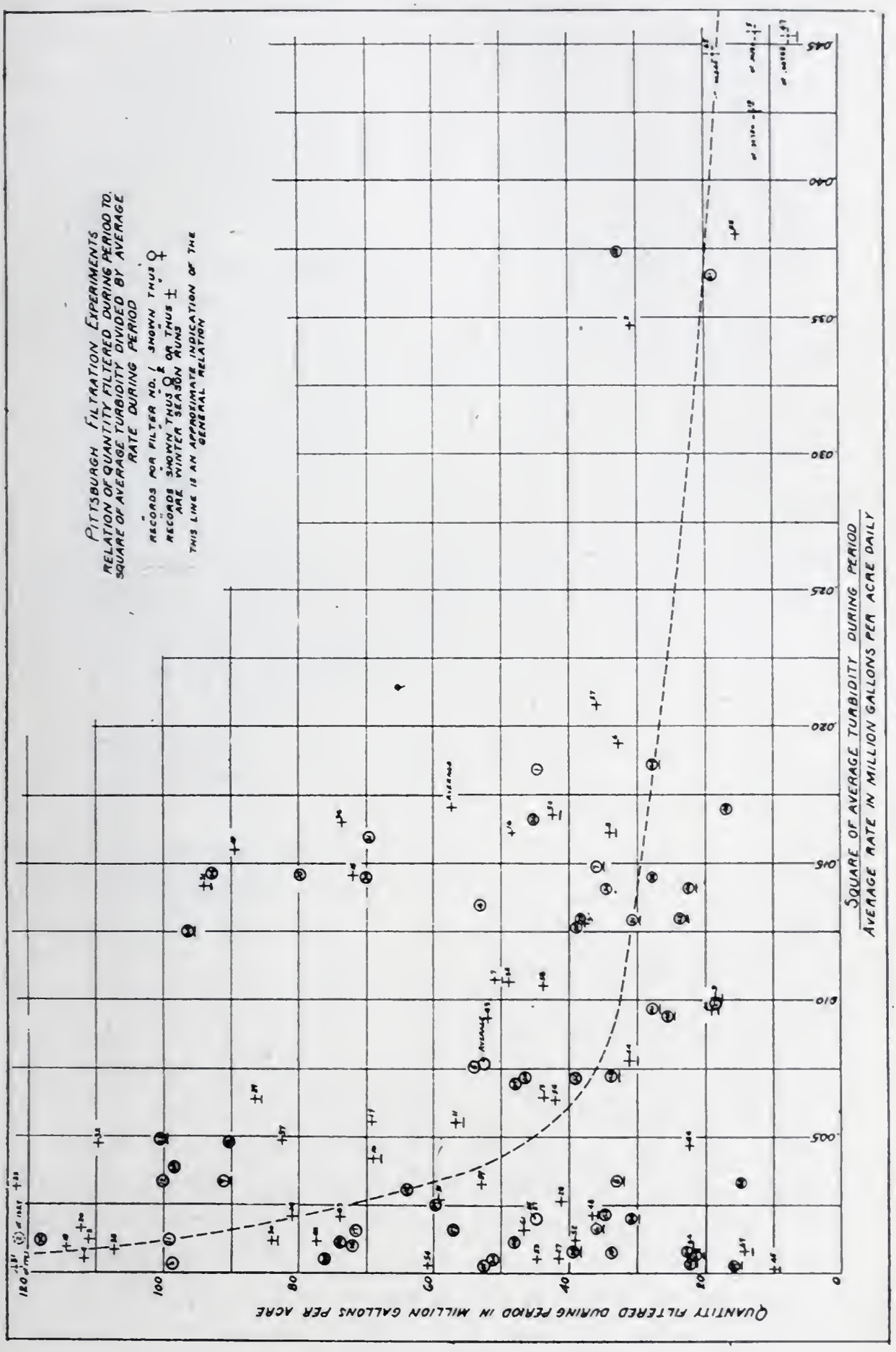

PITTSBURGH FILTRATION EXPERIMENTS
RELATION OF QUANTITY FILTERED DURING PERIOD TO SQUARE OF AVERAGE TURBIDITY DIVIDED BY AVERAGE RATE DURING PERIOD
RECORDS FOR FILTER NO. 1 SHOWN THUS ⊙
RECORDS SHOWN THUS ○ OR THUS ± ARE WINTER SEASON RUNS
THIS LINE IS AN APPROXIMATE INDICATION OF THE GENERAL RELATION
QUANTITY FILTERED DURING PERIOD IN MILLION GALLONS PER ACRE
SQUARE OF AVERAGE TURBIDITY DURING PERIOD
AVERAGE RATE IN MILLION GALLONS PER ACRE DAILY
0
20
40
60
80
100
005
010
015
020
025
030
035
040
045

Fig. 21.

ing a very convenient one for untrained men and out-of-door observations, is not an accurate one, and has quite a percentage of error. Probably, also, not all of the effect upon the clogging of a filter is told by obtaining turbidity, as the size and character of the clay and suspended matter and whether there is much at the beginning of the run to dose onto a raw sand surface, all affects the length of the run.

Upon the diagram in Figure 21 there is plotted the results of the various periods, the ordinates being the quantity of water filtered and the abscissae are the square of the average turbidity during the period, divided by the average rate of filtration in million gallons per acre daily. The line drawn upon this diagram is an approximate one, and its position was determined by balancing the results, after disregarding those for the winter season.

It is to be hoped that when the results of the Philadelphia Experiment Station are arranged and tabulated that the relation of turbidity of applied water to the quantity of water filtered will be determined more exactly, as the method of determining turbidity at that place is much more exact and uniform in the results.

There is plotted upon Fig. 22, the results of the Pittsburg Experimental Sand Filter No. 1, compared to condition of the raw river water. This is shown to complete the history of this filter.

In regard to the results obtained at Lawrence, Mass., I have thought it sufficient to give in Table No. 8 the average by years, and give also the highest and lowest monthly records for the raw water, the effluent from the filters and the tap at City Hall. The latter has been given so that the condition of the water when it comes from the filter and when it is served to the people may be compared under the usual conditions. We would expect less numbers of bacteria in the water after passing through the piping system in the city, owing to the removal of organic matter in the water and thus the death of bacteria, on account of not having food to live on. The reservoir, however, in the city of Lawrence is uncovered and organisms and food material have opportunity to enter the water during storage here for about two weeks, which explains the fact that during warm weather the water at City Hall contains more bacteria than the effluent at the filter.

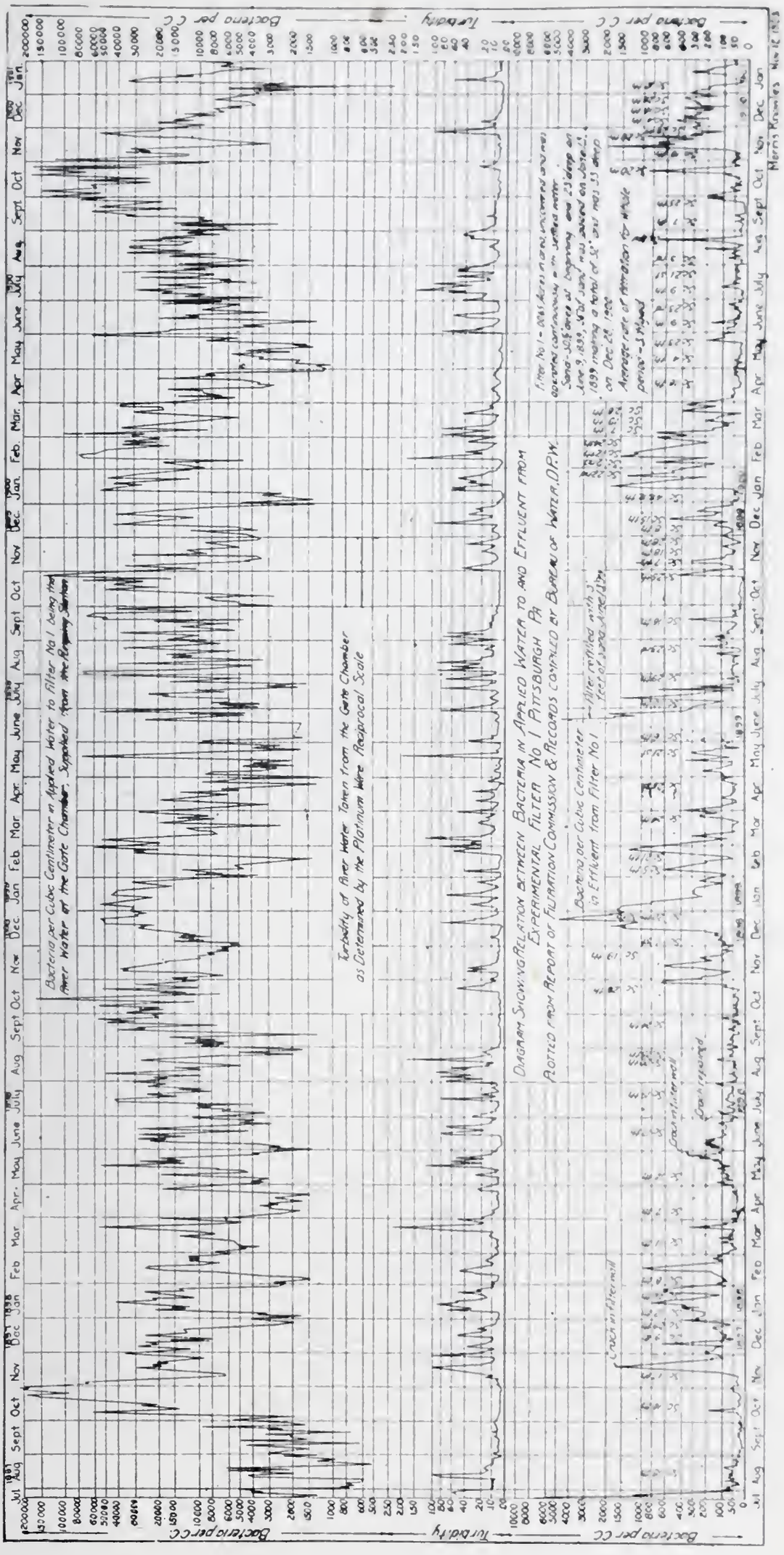

Diagram Showing Relation between Bacteria in Applied Water to and Effluent from Experimental Filter No 1 Pittsburgh Pa
Plotted from Report of Filtration Commission & Records compiled at Bureau of Water, D.P.W.
Bacteria per Cubic Centimeter in Effluent from Filter No 1
Bacteria per Cubic Centimeter in Applied Water to Filter No 1 being the River Water at the Gate Chamber, Supplied from the Pumping Station
Turbidity of River Water Taken from the Gate Chamber as Determined by the Platinum Wire Reciprocal Scale
Bacteria per C.C.
Turbidity
Bacteria per C.C.
Filter No 1 - 0.65 Acres in area, consisting of one cell covering continuously - 24 Million gallons Sand - 3.08 Feet in depth at beginning and 2.3 deep on June 9, 1899, After June 1899 washed on Sundays. 1899 making a total of 51 days on Dec 24, 1900
Average rate of filtration for whole period - 2.3 Million
Filter emptied with 3 feet of Supernatant Water
Cover on Filter roof
Open to atmosphere
Jul Aug Sept Oct Nov Dec Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec Jan
1897 1898 1899 1900
Morris Knowles Nov 12 1903

Fig. 22.

TABLE No. 8.

RESULTS OBTAINED AT LAWRENCE CITY FILTER.

YEARLY AVERAGE, WITH HIGH AND LOW MONTHLY RESULTS.

YEAR.	Average Number of Bacteria Per Cubic Centimeter.			Percentage of Reduction.	
	River Water.	Effluent at Filter.	Tap at City Hall.	Effluent at Filter.	Tap at City Hall.
1883 — Average of three months	12700	320	100	97.5	99.2
1894—Average	10800	150	110	98.6	99.0
High month	23800	360	270	98.5	99.0
Low month	2400	25	92	99.0	96.2
1895—Average	11100	120	80	98.9	99.3
High month	20800	400	100	98.1	99.5
Low month	5000	38	55	99.2	98.9
1896—Average	7600	110	85	98.6	98.9
High month	12600	320	170	97.5	98.7
Low month	3400	34	120	99.0	96.5
1897—Average	10900	57	84	99.5	99.2
High month	34900	68	74	99.8	99.8
Low month	4000	40	100	99.0	97.5
1898—Average	4400	65	66	98.5	98.5
High month	5100	280	260	94.5	94.9
Low month	2300	21	30	99.1	98.7
1899—Average	5800	55	42	99.1	99.3
High month	9800	56	37	99.4	99.6
Low month	1900	17	17	99.1	99.1
1900—Average	9000	54	43	99.4	99.5
High month	12800	110	83	99.1	99.4
Low month	3300	27	28	99.2	99.2
1901—Average	3000	26	18	99.1	99.4
High month	5600	61	34	98.9	99.4
Low month	1300	7	6	99.5	99.5
1902—Average	10300	76	72	99.3	99.3
High month	20900	324	112	98.4	99.5
Low month	2700	32	40	98.8	98.5
1903 — Average of seven months	7400	25	43	99.6	99.4

TABLE NO. 9.

BACTERIAL RESULTS

OBTAINED AT ROXBOROUGH FILTER PLANTS, PHILADELPHIA, PA., JUNE 28 TO NOVEMBER 7, 1903.

WEEK ENDING. 1903.	BACTERIA PER CUBIC CENTIMETER AND TURBIDITY BY SILICA STANDARD.																	
	Schuylkill River at Shawmont.		Eight Upper Roxborough Filters.				Five Lower Roxborough Filters.				Filtered Water Basins.							
			Applied Water.		Average Effluent.		Applied Water.		Average Effluent.		Upper Roxborough.				Lower Roxborough.			
	Bact.	Turb.	Bact.	Turb	Bact	Turb	Bact.	Turb	Bact	Turb	Bact	Pr. Ct. rem'v'd	Turb	Pr. Ct. rem'v'd	Bact	Pr. Ct. rem'v'd	Turb	Pr. Ct. rem'v'd
July 4	26000	60	.....	.....	.....	.....	690	18	53	1	.....	.....	.....	.....	56	91.9	1	94.4
" 11	25000	100	.....	.....	.....	.....	620	32	32	1	.....	.....	.....	.....	35	94.4	1	96.9
" 18	14000	25	.....	.....	.....	.....	520	19	17	1	.....	.....	.....	.....	22	95.8	1	94.7
" 25	33000	170	.....	.....	.....	.....	2900	40	21	1	.....	.....	.....	.....	25	99.1	1	97.5
August 1	16000	26	2300	14	17	3	290	14	21	1	259	89.1	3	78.6	21	92.8	1	92.8
" 8	42000	38	550	13	12	2	260	13	32	1	34	93.8	3	76.9	24	90.8	1	92.3
" 15	36000	30	860	14	24	3	740	15	25	1	24	97.2	3	78.6	22	97.0	1	93.3
" 22	23000	26	830	8	18	2	640	9	26	1	19	97.7	2	75.0	28	95.6	1	88 9
" 29	29000	20	540	7	34	1	1500	9	28	1	140	74.1	1	85.7	28	98.1	1	88.9
September 5	36000	34	860	14	27	1	1400	16	35	1	20	97.7	1	92.9	38	97.3	1	93.7
" 12	18000	28	820	13	46	1	890	13	34	1	41	95.0	1	92.3	38	95.7	1	92.3
" 19	18000	21	750	11	48	0.5	770	12	31	0	42	94.4	1	90.9	28	96.4	0	100.0
" 26	26000	24	780	11	22	0	950	11	33	0	24	96.9	0	100.0	28	97.1	0	100.0
October 3	43000	12	1200	7	31	0.2	1500	9	25	0.1	15	98.7	0	100.0	39	97.4	0	100.0
" 10	37000	100	2500	8	24	0.1	2600	11	38	0.2	21	99.2	0.5	93.7	28	98.9	0	100.0
" 17	17000	38	3100	28	19	0.4	2800	28	84	0.6	23	99.3	0.5	98.2	77	97.2	0.5	98.2
" 24	9800	13	600	14	16	0.5	730	16	16	0.4	12	98.0	0.5	96.4	22	97.0	0.5	96.9
" 31	4200	11	590	9	10	0.1	1300	8	12	0.1	12	98.0	0	100.0	13	99.0	0	100.0
November 7	8800	7	310	6	7.5	0.1	440	2	12	0.1	8	97.4	0	100.0	13	97.0	0.5	75 0

However, there is a material decrease during most of the year, and at no time are there any results which make it necessary to cover the reservoir at this particular place.

The results of the two plants which have been in operation at Philadelphia for some months are given in Table No. 9. These are among the most satisfactory figures which have been obtained for a filter plant, and are especially so because they are results for a short time after the plant has been in operation, and it is a generally expected fact that results in the early history of the plant will not be as good as later. However, many of the figures given in this table are just as low as have ever been obtained in the older plants of the world.

Table No. 10.

Summary of data for several slow, sand filters:

ITEMS.	Bremen, Germany.	Lawrence, Mass City Filter.	Lawrence, Mass., Experimental Filters. State Board of Health. 3-B.	8-A.	Albany, New York.	Mount Vernon, N.Y.	Pittsburg Ex. Filters
Time included	1900-1902	1893-1900	1893-1899	1893-1899	1899-1900	1896-1900	1897-189
Average rate Mgad	1.70	1.25	2.35	2.77	2.60	1.70	2.90
" period between scrapings in days	.32	.29	.26	.29	.25	.24	.23
Mg. between scrapings	.55	.36	.62	.80	.66	.41	.68
Scrapings per year	11.	13.3	13.8	12.6	15.	15.	17.
Average inches removed each scraping	0.98″	0.75″	0.49″	0.53″	0.71″	0.61″	1.05″
Cu. yds. per acre removed each scraping	132	101	65.	71.	95.	82.	141.
Hours labor each scraping and wheeling out	336	228	.....	.....	176	.....	.....
Sand washed in cu. yds per hr.	2.61	0.58	.....	.....	0.64	.....	.....
Vol. of water to sand	7 to 8	10	.....	.....	12.5	.....	.....
Hours labor sanding per cu. yd	2.5	1.5	.....	.....	1.3	.....	.....

In table No. 10 there is given a statement of the items of operation for various filter plants, which may be used as a rough guide of what may be expected for the Pittsburg municipal plant. and thus serve as indicating the cost of maintenance compared to other places.

OPEN OR COVERED FILTERS?

BY FRANS ENGSTROM.

In affixing the question mark to the title of my paper I am only following old and well established precedents; old, as the first paper read before our Society appeared in that dress, and well established in that at least three of our illustrious past presidents used that method of asking for information upon certain subjects that they presented for discussion. It has, besides, the enormous advantage that the author need not be guilty of overwhelming his audience with facts and figures that will force them to yield to his views. On the contrary, after letting himself down as gracefully as possible without displaying too much ignorance on the subject, he leaves them to draw their own conclusions and their conscience need not smite them should they choose to stick to their old, more or less well founded, notions.

I am not going to quote that saying about the patient when the doctors disagree, but

in 1899 Mr. Allen Hazen, consulting engineer of the Pittsburg Filtration Commission, over his own signature says officially about covering the filters: "I do not regard this as necessary, and I do not recommend it."

The commission subsequently concurred in the engineer's views and recommended his plan for adoption.

In 1903 city councils are officially informed by the Department of Public Works that $810,000 are needed for covering the filter beds.

Thus the conclusions of the experts seem to be slightly contradictory and it looks like a case where you pay your money and you take your choice — particularly, take your choice. From more than one point of view such a state of affairs is, indeed, deplorable and against the interest both of the engineering profession and the client. It does not serve to strengthen the standing of the profession in the public eye, nor does it help the work along to an early completion.

Whether or not people, afflicted with the habit of drinking water, should be offered diluted mud with a stick of typhoid germs in it, is a question of such vital and common interest that even a non-expert may be permitted to seek enlightment upon it; and my aim is to throw some light on one small part of the important question to facilitate its being properly understood.

But the art of water filtration is still in its infancy with us, whereas Europe has the advantage of an experience covering over half a century. It was, therefore, in that direction I was looking for the reasons upon which the experts may have based their conclusions. And in the transactions of the Hygienic Congress, held in Copenhagen this summer, I found a paper on the water works in Sweden by Captain of Engineers F. V. Hansen, Chief Engineer of Stockholm Water Works. I will try to give you an abstract of such parts of it as have a bearing on the question before us.

As an introduction it might be pointed out that the engineers over there probably could base a claim to know something about filtration on the fact that every city and town in the whole country with 10,000 inhabitants and over have their own municipal water works **AND FILTERING PLANTS.** The reason for this is not hard to find. "The water works in Sweden have never been subject to business speculations but have always been considered as institutions for the health and benefit of the people."

The original paper covers some fifty communities, but to economize with space I have in the table below omitted all towns with less than 15,000 inhabitants, only keeping the two first ones on account of their northern situation.

City.	Population. 1901 Census.	Minimum temperature of water as delivered.	Area of filter beds, in acres.		Remarks.
			Open.	Covered.	
Östersund	7,000	.....	.....	0.040	
Hernösand	8,100	32.9	.....	0.084	
Sundsvall	15,000	32.5	0.219	.....	
Gefle	30,100	35.6	.....	.....	Supply taken from wells and springs.
Upsala	22,800	44.6	.....	.....	
Örebro	22,900	44.6	.....	.....	
Eskilstuna	17,000	33.8	0.119	.....	
Stockholm	301,700	34.0	4.376	.....	
Norrköping	41,100	37.4	0.356	.....	
Gothenburg	132,100	32.9	2.014	0.534	
Borås	15,900	39.2	0.172	.....	
Jönköping	23,700	.....	0.255	.....	
Halmstad	15,600	.....	0.087	.....	
Carlskrona	24,600	.....	0.346	.....	
Helsingborg	25,200	41.0	0.133	.....	
Lund	17,000	37.4	0.160	.....	
Malmö	62,300	.....	.....	0.346	

To summarize: Out of the 17 places quoted, 3 take their water from springs, 3 have covered filters, 1 has both kinds and 10 have open filters.

Open filters way up there; what is the latitude?

A glance at the map will show you Stockholm on the 59th parallel about, that is 18 degrees north of Pittsburg, and Östersund, a little above the 63rd. We Pittsburgers consider Duluth as being pretty far north, but you can figure out for yourself that Östersund, for instance, is just as far north of Duluth as Duluth is north of New Orleans.

To make a comparison only on difference in latitude would, however, be misleading, as it is well known that the Gulf stream has a considerable influence on the temperature of Northern Europe, making it inhabitable far above the possibilities of the northern part of this continent.

The mean temperature would probably better indicate the conditions and I give in the table below such information as I could reach at this writing.

MEAN TEMPERATURES IN DEGREES, FAHRENHEIT.

Station.	Annual.	Jan'y.	Station.	Annual.	Jan'y.
Östersund	35.0	15.3	Stockholm	41.4	26.1
Hernösand	37.1	20.0	Gothenburg ...	44.4	29.8
Gefle.....	40.0	24.5	Jönköping.....	42.7	28.6
Upsala	40.4	24.5	Halmstad	44.8	30.5
Örebro	41.6	25.8	Lund	44.9	31.3

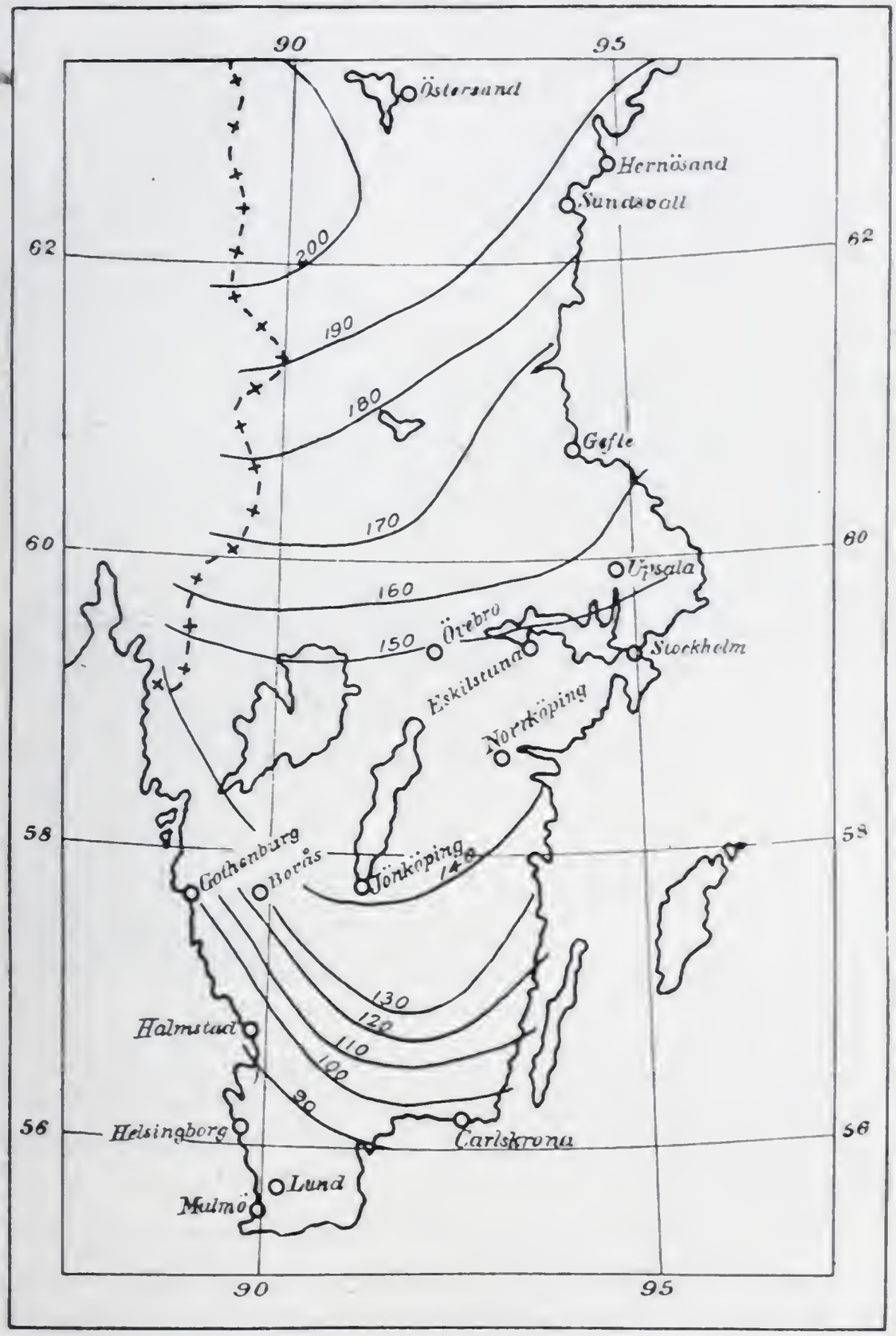
You will notice that the two first ones have a mean annual temperature hovering close above the freezing point; so we will excuse them for covering up their filters.

If it be granted that the danger of freezing is a very important factor in deciding whether covers are needed or not, the duration of the cold spell at a certain locality would indeed offer the best basis for your conclusions.

In poetical language Sweden has been called the land of the thousand lakes; very few of these, however, are of any great extent, but nearly one-twelfth of the whole surface of the country is covered with water. Observations made during a long period of years at a great number of stations have furnished data as to the time of freezing and breaking up of these inland lakes. From these data were constructed the "equiglacial lines," or lines of equal ice periods. I have reproduced these lines on the accompanying sketch map. The figures on the lines indicate the average number of days per annum the lakes remain frozen.

You will observe from this map that at Östersund the adjacent lake is frozen close up to 200 days every year. We will again excuse them for using covers. A little farther south you will find that Hernösand and Sundsvall both have an ice period of about 185 days; the one has covered the other open filters. Going farther south, to Stockholm for instance, we notice that they have beautiful skating ice on the lakes for say 145 days every season.

And do they leave their filter beds open? Yes; and that is no experiment either. I saw them myself in successful operation over twenty years ago.



SKETCH MAP OF PART OF SWEDEN, SHOWING EQUIGLACIAL LINES.

THE FIGURES ON THE LINES INDICATE THE AVERAGE NUMBER OF DAYS PER ANNUM THE INLAND LAKES REMAIN FROZEN.

Let me quote what Capt. Hansen says on this point to-day:

"A question pertaining to sand filters that has caused a great deal of discussion on the continent and about which opinions seem to differ even in Sweden, is whether they had better be covered or left open. The biological researches of recent years have corroborated that the sun light has a particularly beneficial influence on the purification of the water in that it aids the propagation of algæ that give off oxygen. On the other hand, has been put forth the inconvenience caused by snow and ice during the winter. *It is a fact, however, that the climatic conditions at the open filters, in Stockholm for instance, have not caused any inferior filtering results,* and there the operations receive the strictest attention." (*i. e.,* bad results could not have escaped their notice.)

In more northerly locations, especially where exposed to severe snow storms, such as Östersund, among others, they use a superstructure of double plank with isolating filling between. "This inexpensive method has given excellent results."

At a new pumping station some distance from Stockholm, where the filter beds are very much exposed and where it will be difficult to secure help on short notice for removal of the snow, light steel superstructures will be used for protection against the snow. The roofs to be made almost entirely of glass to admit the sun light; the walls to consist of removable wooden doors, that can be taken out in summer time.

"The very expensive method, of German origin, to cover the filters with arches and earth filling can hardly be considered necessary nor even deserve of recommendation, were also abundant funds available."

When confronted with an engineering problem under somewhat new conditions, especially if it involves work of any magnitude, it is always well to familiarize yourself with what other engineers have accomplished in the same line and as nearly as possible under similar conditions.

I have endeavored above to show a few samples of how some engineers have solved the problem before us, and done so suc-

cessfully, not at a two-by-four experimental plant, but under actual working conditions and these conditions were far more severe than we ever can meet here in Pittsburg.

Now, gentlemen, if you are all satisfied, beyond a reasonable doubt, that the City of Pittsburg has $810,000 laying loose around somewhere, for which it can find no better use than to invest it in covers for the filter beds, then you must come to the conclusion that ..... (I leave it blank for you to fill out).

In closing it is very tempting to venture the opinion that the dear, suffering public of Pittsburg pretty soon has a right to expect something more substantial in the filtering line than talk: and that we possibly have had enough of commissions and committees and estimates and reports and opinions, etc., etc. But then, I come to think of a young family of my neighbors that very readily could prove an alibi if indicted for race suicide.

Upon the arrival of No. 6, the five preceding plants flourishing, the madame began to think that she had done her duty and rather emphatically told the attending physician, "This is the last one."

"Why, certainly," the doctor replied, "from all appearances I should say this is the last one — so far."

DISCUSSION.

MR. CHESTER—I think, Mr. President, since it is so late, that we had better have another night to discuss these papers. A great many have gone home, and it is now so late that the benefit of any discussion would be wasted. I think the presentation of a few written discussions would precipitate quite a number of oral ones. It seems to me a very profitable evening might be spent in discussing all of these papers. If it is in order, therefore, I would move that the Program Committee be asked to select a night for the discussion of these papers, and I will leave it to the Committee whether it is to be a special night or otherwise. I would also suggest that they arrange for a few written discussions which I am sure will precipitate oral discussion.

Motion carried.

PROF. KINTNER—I move a vote of thanks be extended to these gentlemen for the very interesting papers presented this evening.

Motion carried.

Adjourned at 11:05 P. M.

CHARLES W. RIDINGER,
Secretary.

The regular meeting of the Chemical section, was held Thursday evening, Oct. 22, 1903, in the rooms of the Society, the Chairman, Mr. H. W. Craver, presiding. The following committee was appointed by the Chair to nominate officers to serve for the ensuing year: Messrs. J. A. Mohr, L. L. Arnold, K. F. Stahl. Mr. Silverman read his paper on "Estimation of Carbon Di-oxide in Air of School Rooms." After discussion, section adjourned.

C. H. Rich, *Secy.*

THE CARBON DI-OXIDE IN THE AIR OF ALLEGHENY SCHOOLS.

BY ALEXANDER SILVERMAN.

For years, study has been made of the effects of Carbon Di-oxide upon man, as well as upon lower animals, and the result of this study is a literature on two views, which views are so well balanced that it would be a very difficult matter for any one to uphold one or the other. Many a man has spent a life-time to prove one view the correct one, only to find his proof balanced by the work of another on the other side of the question.

The one view, of the effects of Carbon Di-oxide on the system, is that it acts as a poison; that it kills gradually by action on the vital parts of the system the same as would any mild poison, and that this can be seen by the injury suffered in close rooms where many people are present.

The other view is that Carbon Di-oxide acts as a diluent of the air and not as a poison. By this is meant that the Carbon Di-oxide exhaled by man, as well as that resulting from the combustion of carbon compounds, tends to lower the percentage of oxygen in the air, by the increase of its own volume. That the increase of Carbon Di-oxide tends to lower the percentage of oxygen is quite true. This decrease affects various parts of the system. It has been proven that combustion of compounds occurs in the blood and the lungs, as well as in the digestive organs, and to be carried out properly, this requires a good supply of oxygen mixed with not more than a certain per cent. of Carbon Di-oxide. The average quantity of Carbon Di-oxide exhaled in

the human breath is about 4.5 per cent., and the quantity contained in pure out-door air is less than .03 per cent. Now, when more than a certain quantity of Carbon Di-oxide is contained in the air, it is difficult for these various organs of the system to carry on oxidation, and they are compelled to do more work to accomplish it. The effect of this change in the conditions to which the body is subjected, is to directly weaken the parts in which combustion takes place and thus indirectly weaken the whole system. Where Carbon Di-oxide is present in large quantities, the effect may be immediate, but where the quantity in excess of .07 per cent. is small, the effect is felt for but a short time, the various organs of the system conforming themselves, gradually, to this changed condition. This conformation weakens them, and, while it does not immediately, it will, in time, cause suffering to the person breathing the air.

Whether Carbon Di-oxide acts as a poison or as a diluent, or as both, is not very material in this work. All who study it, whether as one or the other, agree that vitality is impaired when it is present in excess of a certain per cent., and this being the case, it is important that the air, in school especially, be pure, since the children, there exposed to it, can ill afford an impaired vitality at the beginning of their life work. For this reason I determined the quantity of Carbon Di-oxide in the air of the primary departments of the Allegheny public schools, thinking them a good example of the average system.

A description of apparatus and methods used, as well as tabulated results, follow:

APPARATUS.

The Sample Vessel. The vessel in which the air sample was taken, was a large mixing bottle, found by callibration, with correction for solvent added to absorb Carbon Di-oxide, to contain 7,770 cubic centimeters. This was fitted with a doubly perforated soft-rubber stopper, through which passed two glass tubes, their upper ends bent at right angles. One of these passed to the bottom, while the other protruded an inch through the stopper. Each of these was fitted, at the upper end, with a piece of rubber tub-

ing, containing a glass plug, so that when the stopper was forced in tightly, the sample-bottle was air-tight.

The Pump. The means of drawing air through the bottle was a hand-bellows, fitted with reflex valves. At each drawing, one-half liter of air was removed through the short tube of the sample vessel, this action drawing the air, from the room, into the bottom of it through the long tube. Thus, by a number of drawings, two or three times as great as required to fill the vessel, I obtained a perfect sample of the air of the room. The bellows was connected with the small tube of the sample bottle by a ten-foot hose, so as to prevent the quantity of Carbon Di-oxide, in the sample taken, from being affected by my exhalations.

Method of Determining the Carbon Di-oxide. The Carbon Di-oxide was determined by a standard oxalic acid solution after absorption by Baryta solution. The Baryta solution was made up of such strength that 50 cubic centimeters of it were equivalent to 69 cubic centimeters of the standard oxalic acid solution, one cubic centimeter of which was equivalent to .2493 cubic centimeters of Carbon Di-oxide. Since Baryta solution so readily absorbs Carbon Di-oxide from the air, it was kept in a bottle provided with an inlet air-tube, through which air, freed from Carbon Di-oxide, by having been passed through a ten per cent. caustic soda solution, entered. The outlet was through a siphon tube provided with a doubly bent and finely-drawn-out tip, so as to prevent contact with air, there. A two ounce bottle of this Baryta solution was taken along to the school room, and after the sample of air had been drawn, 50 cubic centimeters, measured in a pipette, were admitted into the sample vessel. At the same time, three drops of a 3 per cent. alcoholic solution of phenolphthalein were added as an indicator. Thus, by titration with oxalic acid, the Carbon Di-oxide was determined by difference. The standard solutions were corrected and made up freshly, from time to time, so as to insure perfect accuracy in the results.

Moisture. The moisture was determined, in the school room, by the use of a dry and wet bulb thermometer. The government tables were used for calculations.

Taking of the Sample. The vessel was placed as near the

middle of the room as possible, at a height of three feet from the floor. As a precaution against drawing in air exhaled by children immediately surrounding the vessel, I had the three middle rows of each room vacated. The air was drawn into the sample vessel as already explained. The 50 cubic centimeters of Baryta solution were then added together with the 3 drops of phenolphthalein solution. Corking the bottle tightly, and sealing as previously explained, I took it to the laboratory, where it was rolled for twenty minutes to insure perfect contact of the particles of air and Baryta solution. The solution and precipitate, formed by the Carbon Di-oxide, were then run into a burette, which was immediately closed at the top by a rubber stopper. When the precipitate had subsided it was run off, and 35 cubic centimeters of the remaining solution titrated with standard oxalic acid solution.

Of the twenty-two samples taken in the primary grades of the Allegheny public schools, the following table shows the per cent. of Carbon Di-oxide, calculated for the sample as taken, and also for dry air:

No. of Sample.	Date.	Time when taken.	Height of Barometer M. M.	Temperature in °C.	Carbon Di-oxide.	
					Moist Air.	Dry Air.
1	April 22, 1902	10.30 A.M.	733.6	25°	.1392%	.1420%
2	" 23, "	11.10 "	732.1	24°	.0495%	.0502%
3	" 24, "	11.00 "	740.1	20.5°	.0561%	.0568%
4	" 25, "	10.40 "	736.9	21°	.1723%	.1750%
5	" 28, "	2.30 P.M.	737.8	24°	.0372%	.0374%
6	" 30, "	2.40 "	735.4	23°	.0647%	.0658%
7	May 1, "	2.05 "	739.7	23°	.0697%	.0706%
8	" 5, "	2.40 "	735.8	23°	.0455%	.0462%
9	" 6, "	2.25 "	735.3	27°	.0532%	.0543%
10	" 9, "	2.00 "	736.2	20°	.0547%	.0558%
11	" 12, "	11.15 A.M.	736.6	20°	.2006%	.2038%
12	" 12, "	2.40 P.M.	736.6	23°	.0681%	.0693%
13	" 16, "	2.20 "	736.8	21°	.1369%	.1394%
14	" 19, "	11.00 A.M.	732.8	24°	.0751%	.0778%
15	" 19, "	2.15 P.M.	732.8	26°	.0540%	.0552%
16	" 20, "	2.15 "	735.3	26°	.0371%	.0379%
17	" 21, "	2.43 "	739.4	25°	.0714%	.0728%
18	" 22, "	10.30 A.M.	737.4	25°	.0447%	.0457%
19	" 23, "	10.30 "	735.3	26°	.0410%	.0420%
20	" 23, "	3.00 P.M.	735.3	26°	.0444%	.0450%
21	" 27, "	2.20 "	732.2	18°	.0989%	.1002%
22	" 28, "	2.15 "	732.4	20°	.0520%	.0527%
Average.					.0748%	.0770%

From this table it will be seen that the minimum amount of Carbon Di-oxide found in any sample was .0371 per cent. for moist air and .0374 per cent. for dry air. The maximum amount found was .2006 per cent. for moist and .2038 per cent. for dry air. This latter is exceedingly high for air in schools. The average quantity of Carbon Di-oxide found was .0748 per cent. for moist and .0770 per cent. for dry air.

Considering air which contains from .03 per cent. to .05 per cent. as very good, that containing from .05 per cent. to .075 per cent. as good, that containing from .075 per cent. to .1 per cent. as poor and that containing more than .1 per cent. as very poor, and even dangerous for breathing purposes, I found 31.81 per cent. of the samples very good, 40.91 per cent. good, 9.09 per cent. poor and 18.18 per cent. very poor.

NOTE.—These samples were taken at a season of the year when rooms could be ventilated properly without the use of any mechanical system.

CHEMICAL SECTION.

The regular monthly meeting of the Chemical Section, was held in conjunction with the Pittsburg Section of the American Chemical Society, in the rooms of the Engineers' Society, Thursday evening, November 19th, 1903, the Chairman, Mr. H. W. Craver, presiding.

The minutes of the last regular meeting were read and approved.

Dr. Stahl, Chairman of the committee nominations, reported for the committee the following nominations: For Chairman, Mr. H. E. Walters; Vice Chairman, Mr. H. W. Craver; Secretary, Mr. Geo. P. Maury; Directors, Mr. Geo. Leoffler, Mr. C. H. Rich.

Mr. J. O. Handy, read his paper as announced, "The Chemistry of Water Softening." Mr. Handy displayed a number of drawings and presented a most thorough and able paper.

After a general discussion, the Section adjourned.

CHAS. H. RICH, *Sec.*

STRUCTURAL SECTION.

A meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held at the Society's hall, 410 Penn Ave., Pittsburg, on Tuesday, Nov. 24, 1903.

Meeting called to order by the Chairman, Mr. J. K. Lyons, at 8:30 P. M., 16 members and visitors being present.

Minutes of the previous meeting were read and approved.

Discussion of the subject for the meeting, "Concrete Steel Construction," was participated in by Robert A. Cummings, Richard Khuen, Jr., Emil Swensson, and others.

Subject selected for discussion at the December meeting, "Railroad Bridge Construction."

Subject selected for discussion at the January meeting, "Highway and Trolley Bridge Construction."

On motion, Section adjourned at 10:45 P. M.

WILLIS WHITED, *Sec.*

STEAM BOILERS FOR POWER PLANTS.

BY W. D. CHESTER.

When all the boilers which are to be installed in the power plant of the New York Subway are operated at their normal rated capacity the energy contained in the steam which they deliver per minute will be equivalent to the work required to raise a 4,000,000 pound weight one mile in one minute. Their maximum contract capacity is fifty per cent. in excess of this.

If of the enormous quantity of energy absorbed from the coal pile by these boilers and their furnaces, 12½% is available at the engine crank shafts for useful work, the designing engineers, the constructors, the operators, and the owners of this great plant will indeed have cause for congratulation.

Of the energy contained in the steam produced by the boilers of this plant, over 90%, useless for power producing purposes and, to a small degree, dissipated by radiation from piping and engine cylinders and by cylinder condensation, will pass into the condensers and down the Hudson River.

A steam boiler with its furnaces is an essential part of an apparatus for utilizing some of the physicial properties of water to transform energy from the coal pile to the crank shaft.

Aside from a few early applications of steam for operating mechanical toys, the history of the steam boiler, dating from the operations of Savery and Papin at the beginning of the eighteenth century, down to the present time, is an interesting and highly instructive study.

It was eventually found that the heat absorbing and conducting properties of water and of the products of combustion, were such as to necessitate the subdivision of one or the other or both, so as to increase the area of contact of the boiler surface with the water on one side and the products of combustion on the other, if anything like a paying utilization of fuel-cost was to be obtained. This necessity for subdivision led to the development of the two principal types of boiler, one, known as fire-tube boilers,

in which the products of combustion are subdivided and carried through the water, the other, known as water-tube boilers, in which the water is subdivided and carried through the products of combustion.

Before considering these two types of boilers in their relation to power plants, it will be well, perhaps, to consider some of the properties and qualities of the natural elements as required for use in steam generating plants.

These elements are fuel, containing carbon and other substances; air, the oxygen of which chemically combining with certain elements in the fuel, produces the natural phenomenon and manifestation of energy called combustion; and water, the natural properties of which are used to convey and transform the heat energy into mechanical energy, much the same as an electric current conveys energy from the shaft of the generator to that of the motor.

Feed water may contain anything that will float, some things that wont float, anything that will dissolve, and many things that only mix.

While a few of the things besides what was originally rain water that go into a boiler are evaporated, most of them never reach the dry pipe. If everything that comes to a boiler from the feed pump went through the throttle valve, there would be fewer boiler makers and many more in the cylinder oil business.

The boiler maker and designer and the power plant engineer are confronted by the fact that pure water for feeding purposes is a rarity, and provision for that fact must be made in every case, or disaster and expense, to say nothing of loss of fuel, are sure to follow.

After the boiler designer has made every provision for collection and removal of foreign bodies, sediment and deposit incidental to the worst kind of feed water, each case requires continual individual and intelligent treatment. Analyses of water taken from boilers in service, are often startling, if they do not reveal a condition of affairs a little short of criminal.

The treatment of water before it goes into the boilers and its care after it goes in are subjects deserving much more at-

tention than they receive. Each plant is a study by itself, not for a while but for all time, for the quality of most feed water changes with the seasons if not from day to day.

Coal, the bitumen or petroleum group of fuels, wood and natural and producer gas, are, of course, the principal fuels available in power plants, while to a minor degree by-products and waste gasses incidental to industrial processes are used, not to mention peat, sawdust, tanbark, straw, bagasse and many other substances. Each fuel has a characteristic *process* of combustion with characteristic *products* of combustion and characteristic temperatures. A furnace for one would be unsuitable and utterly inefficient for another. A boiler manufacturer who undertakes to provide a boiler without either knowledge of the fuel to be used or assurance that the purchaser understands his proposition, is courting trouble or, to say the least, speculating.

Aside from coal the use of the fuels mentioned above is purely local, each requiring individual furnace conditions and proportions to give anything like efficient results.

At the present time coal is, of course, *the* fuel in use in power plants. The varieties of coal and the consequent varieties of furnace treatment to get the utmost possible efficiency, are as extensive as all the different kinds of fuel mentioned above.

The principal constituents of coal are moisture, volatile matter or hydrocarbons, fixed carbon and ash, with minor constituents of a metallic or similar nature.

The grading and treatments of coals are determined by the relative amounts of each of the principal constituents, the boiler designer having to do principally with the relative amounts of volatile matter and fixed carbon, on which depend, usually, the most efficient rate of combustion. Generally speaking, coals low in volatile matter and high in fixed carbon, belonging in the anthracite group, are slow burning under natural conditions, while at the other extreme, coals high in volatile matter and low in fixed carbon are quick to ignite and rapid in consumption under natural conditions. Between these two limits are coals moderately high in fixed carbon and carrying correspondingly less volatile matter. For example: Pennsylvania anthracites run 3 to $4\frac{1}{4}$ per

cent. volatile matter, 80 to 85 or even 86 per cent. fixed carbon; semi-bituminous, such as Clearfield, 20 to 25 per cent. volatiles, 65 to 75 per cent. fixed carbon; and bituminous, such as Pittsburg, 50 to sometimes over 70 per cent. volatiles, with 35 to 50 per cent. fixed carbon.

In the average small hand-fired power plant, operated by natural draft, the usual rates of combustion per square foot of grate per hour for most efficient results are:

For anthracite	8 to 12 lbs.
For semi-bituminous	12 to 20 lbs.
For bituminous	15 to 24 lbs.

with corresponding variations in furnace temperature and consequently of products of combustion from which the boiler must absorb the heat required for steam generation.

Upon the relative proportions of the ingredients of coal depends the amount of heat generated by the perfect combustion of a unit quantity and hence its theoretical steam making value.

Coal having as low a theoretical heat producing value as 10,000 B. T. U. per pound, would be called a poor coal, while the best grades run as high as 14,000 to 14,750 B. T. U. per pound.

While laboratory determinations of fuel are valuable and, to the power plant designer, essential in laying out the boiler plant, the chief cause of low efficiency is usually found at the grates, either from improper handling of the fires or from improper distribution of heat absorbing surface above the grates. The efficiency of a steam generator is the product of the efficiency of the furnace into the efficiency of the boiler itself. The function of a boiler is to absorb heat, to a certain extent store it and deliver it as required for use. Upon its design and the distribution of its details depend its efficiency and flexibility as a heat absorber. Upon the design and proportion of the furnace depends its efficiency as a generator of heat for the purposes of the boiler. Furnace design and efficiency is a study (and a mighty interesting one) by itself, but for the purpose of this paper to be merely referred to superficially.

It will be seen that a steam boiler is an apparatus for gen-

erating steam from water containing varying degrees of soluble and insoluble material, with fuel widely varying in physical and chemical properties and in calorific value. Human ingenuity coupled with business necessities and service requirements has evolved many types and designs of steam boilers, all separable into two groups or classes—Fire Tube and Water Tube.

While the former was the gradual growth from the ancient forms of boiler, the latter has been a development to meet the requirements of comparatively recent years.

The fire tube is preëminently the small plant boiler, while the water tube is as much so the large plant boiler. Externally-fired, cylindrical, horizontal and vertical tubular; and internally-fired marine and locomotive boilers are the distinctive types of fire tube, while the sectional and the non-sectional are the distinctive types of the water tube.

Each of these types of boiler has its limitations of combined efficiency and unit capacity, determined mostly by essentially individual structural characteristics.

The efficiency of the boilers of locomotives in the face of the exceedingly high rate of combustion and consequent high temperature of furnaces and escaping gases has been a source of wonder and has developed the fact that, generally speaking, with most any grade of fuel, the higher the rate of combustion in a properly designed and operated furnace, the higher the furnace efficiency.

To attain high boiler efficiency, it is necessary to so distribute the contact between furnace gases and heating surface as to reduce the temperature of the escaping gases to, as near as possible, the temperature of the water in the boiler. As the most efficient engine is the one in which the difference between the temperature of the steam entering and that leaving is the greatest, so is the most efficient boiler the one in which the difference between the furnace gases and the flue gases is greatest for any assumed fuel.

Structural and safety limitations to combined capacity and efficiency in fire tube boilers are reached much quicker than in water-tube boilers, that is to say, assuming a given grate area and assuming that practically the amount of fuel that can be burned

on a given grate is determined by the draft and furnace possibilities, the structural and safety limit to unit capacity is reached much quicker in a fire-tube than in a water-tube boiler; in fact, the size of a sectional water-tube boiler is limited not by structural considerations nor by safety, but by structural restrictions of the furnace.

The result is, that with possibly a few exceptions in mills with constant loads and in a few cases where individual prejudices or lack of knowledge of the subject to be dealt with have been allowed full sway, fire-tube boilers are unused in large central power stations. The sectional water-tube boiler is almost universally used in the modern power plant in this country and in Europe.

We shall confine ourselves, therefore, to the consideration of a few of the principal types of both fire and water-tube boilers for power plant purposes, as affected by consideration of feed water, fuel, safety, and range of combined efficiency and capacity, touching, to some extent, on the subject of unit sizes and on superheated steam.

The records of the Patent Offices of all countries show that much thought has been given to the subject, and also point to the proneness of engineers to consider slight alterations of old designs improvements, without giving due consideration to the features guiding steam boiler engineering; one of the branches of mechanical science requiring more patient research, experiment and experience than almost any other—embracing not only knowledge of mechanical construction, but of physics and chemistry.

The fact that a boiler is patented, by no means proves that it does not contain elements of construction that have been tried and that have failed.

There are in use in this country two distinctive types of fire-tube boilers: The horizontal and the vertical.

Of the horizontal we may mention:

1. The plain cylindrical boiler.
2. The Cornish or single-flued boiler.
3. The Lancashire or double-flued boiler, including the Galloway.

4. The cylindrical tubular.
5. The locomotive type.
6. The Scotch marine type.

There are numberless combinations of these six distinctive types or classes which have been made in this country, and European engineers are particularly prone to producing compound and complex designs of endless variety.

The plain cylinder boiler still in use in some antiquated plants, usually about 30 inches diameter by as high as forty feet long, is simplest, while the varieties of the marine with the complications of stay bolts, flat surfaces and, in some cases, corrugated furnaces, go to the opposite extreme of complexity.

The cylindrical tubular is really the representative type of the horizontal fire-tube type for land purposes and in point of numbers, anyway, is the most extensively used boiler in the country.

The vertical fire-tube boiler is, generally speaking, a small boiler, although the Reynolds, the Dean & Main and the Manning boilers are all among modifications of this type used to some extent in moderate sized units.

Locomotive or fire-box boilers are used in many cases where portability or other considerations seem to make them necessary. There are engineers who think that there can be no such thing as a boiler without a mass of stay bolts and stay tubes. Dr. E. D. Leavitt has designed and constructed for the Calument & Helca Company, locomotive type boilers which are examples of the extent to which the locomotive idea can be successfully carried in stationary practice.

Fire-tube boilers are often designated as "shell" boilers because one of their distinctive features is a shell or cylinder containing the water through which the fire tubes pass. All shell boilers are explosive,—and the structural and safety limitations to the size of the shell are the limitations to size of individual units. The subject of boiler explosions is a gruesome one and has been a fertile field for research and speculation. No one can feel safe in an office above a shell boiler.

At or about their nominal rating, shell boilers, when clean,

are probably as efficient as any type, but their design necessitates short passages for subdivided gases and correspondingly short time of contact of gases with subdivided heating surface; hence, rapid combustion with high furnace temperatures means high temperature of flue gases and low efficiency.

Comparatively pure feed water is an essential with shell boilers, for the reason that most of the evaporative surface is inaccessible for mechanical removal of the scale and deposits incidental to the use of feed water containing any degree of hardness or solid material, the gradual accumulation of which is accompanied by corresponding decrease of efficiency and increase of coal and repair bills.

Fire-tube or shell boilers may be summarized as being efficient at or about their normal rating only with clean feed water, of limited unit capacity, rather low in first cost, and, by their structural limitations of design, necessarily subject to disastrous and death dealing explosions.

With the exception of the case of so-called "flash" boilers, which are seldom used except for very small units, such as for automobiles, there are essentially two parts to water-tube boilers; namely, the tube surface and details directly subject to furnace heat, and the steam and water drum. The drum is really a separator in which the steam generated in the tubes is separated from the water in circulation and stored for use as required.

As a steam generator, the drum or drums, as the case may be, is really insignificant.

The distinguishing features of each of the various types of water-tube boilers are:

First: The relation as regards position between the steam generating tubes and the steam separating and storing drum or drums;

Second: The manner in which the tubes are connected to the drums.

There is a difference of from 1,500 to 2,000 degrees between the temperature of the furnace and the temperature of the gases leaving a well-proportioned boiler and furnace.

The strains incidental to such great differences in temperature are incalculable in amount and in variety.

Flexibility is an essential requisite on this account, obtained in various ways but in many cases only partially.

The high pressures called for by engine builders, increased lately by the demands of steam turbines, necessitate the avoidance of large pressure resisting areas, particularly where high temperatures prevail, and the use of small elements to get the high heat conductivity of thin metal walls.

Again, as ruptures are bound to occur, a design which localizes and so minimizes the effect and distribution of any rupture is an essential for safety with high pressures and high furnace temperatures, particularly in the case of larger plants, the total disability of which would be accompanied by incalculable loss and personal discomfort.

An enumeration and description of the various kinds of water-tube boilers on the basis of the relation between the tubes and the steam drums would be at this time out of the question, for it is too vast a subject. On the basis of the manner in which the tubes are connected to the drums there are two distinct types, the non-sectional and the sectional. In the non-sectional the entire assemblage of tubes is connected, through the medium of a single chamber, be it called a "header," a "water leg," or a "cylindrical drum," to the steam drum, where the separation of steam from the water takes place.

In the sectional the tubes are divided up into entirely independent elements, each a small steam generating unit by itself, consisting of tubes connected at each end to manifolds or headers, each unit having its individual connection to the steam drum. As a result there is a flexibility and an element of safety incidental to the sectional construction which is the reason for the entire absence of disastrous and death dealing casualties with this type of boiler.

Again, with the tendency to large power generating units there is a demand for large steam generating units, which this type of construction safely and economically meets.

The non-sectional water tube boiler is a compromise between

the sectional water tube boiler on the one hand, and the horizontal or vertical cylindrical or the locomotive types of fire tube boilers on the other. As examples of the non-sectional, may be mentioned the Heine, Edgemoor, Geary and others of similar design, in which all the tubes tributary to a steam drum are connected to it by a rectangular water box strengthened by stay bolts, following locomotive practice. As examples of non-sectional boilers with tubes vertical, or nearly so, may be mentioned the Cahall, Wickes, Climax, Cook and Stirling, all following cylindrical tubular practice, vertical and horizontal to a large extent. Of the sectional water tube type the principal examples are The Babcock and Wilcox, Abendroth and Root, National and Campbell-Zell.

In manufacturing plants the load curve and consequent demand for steam, varies but little from hour to hour, consequently, aside from considerations of safety and accessibility for cleaning and repair, the selection of a type and size of boiler demands principally acquaintance with the individual characteristics of the boiler, as to its most efficient rate of steam generation and the proportion of heating surface to grate surface required for the fuel used. The same is true to a certain extent in rolling and steel mill practice where steam is usually largely a by-product of the process of manufacture, although adaptability to considerable and sometimes sudden variation of steam demand is an essential.

It is in the modern central electric light and power station that the most exacting demands are made upon the steam generators. In one of the largest power plants in New York City, peak loads as high as 37,500 kilowatts are of daily or rather bi-daily occurrence with an average of less than 7,000 kilowatts, and a minimum of less than 2,000 kilowatts.

The peak loads last for about an hour in the morning and for an hour to an hour and a half in the evening. Storms, fairs, and unusual assemblages of people at one point, throw upon the boiler plant sudden and often unannounced demands for steam, which must be met at once to save the good-will of the people, which is so essential to all corporations performing public service.

The boiler best adapted to this sort of service is one having

a wide range of combined maximum evaporative efficiency and capacity, quick steaming capabilities, ease of access for completely removing scale where bad water is used, must be a quick steamer, and when large generating units are used, should be of a design permitting large units without losing its elements of safety, accessibility and efficiency.

There is in Washington a large power plant equipped with marine boilers in which it is necessary to begin to get up steam five to six hours before the peak load comes, or rather is due. As a contrast to this, and as showing the possibilities of the sectional water tube boiler, is a case in mind in which a 265-horse-power water tube boiler was blowing off steam at 215 pounds pressure in less than fifteen minutes after fire was lighted in a cold furnace with the water in the boiler at 72 degrees Fahrenheit. An emergency capacity test of this same boiler of three and one-half hours duration, showed an average of $13\frac{1}{2}$ pounds of water per hour, per square foot of heating surface, or four and one-half times its nominal rating, and that without the slightest sign of straining or overheating in any respect.

The average rate of combustion on this test was $59\frac{1}{2}$ pounds of Pocahontas coal per hour, per square foot of grate surface; and the water evaporation 10.15 pounds of feed water from and at 212 degrees per pound of combustible. This was a standard size and type of boiler which has repeatedly shown its ability to successfully, and without sign of distress, duplicate this performance.

The requirements for a boiler suitable for the power plant of to-day are more and more approaching marine practice, and a closed fire room under pressure of air is by no means a remote possibility of the future power plant.

Some changes in furnace and stoker design and practice may be necessary, but the fact that high rates of combustion do not materially decrease furnace efficiency is so well established, and the possibility of obtaining a boiler which will safely and economically temporarily maintain a high rate of evaporation, are forcing some radical changes in boiler room engineering practice. It has been already stated that, of the energy ab-

sorbed from the furnace by each pound of feed water, a large amount is useless for power purposes; part being lost by radiation, part by cylinder condensation, and by far the greater part passes off in the cooling water of the condenser.

The aggregate of these losses is practically constant and is independent of the steam pressure. The more heat each pound of feed water absorbs in changing to saturated steam, the smaller the ratio which the lost heat bears to the heat energy utilized. The amount of heat energy contained in each pound of saturated steam from an assumed temperature of feed water depends upon the pressure at which the steam was generated. If the steam after its gneration is subjected to a source of heat of higher temperature, it absorbs more heat energy, becomes hotter than the temperature due to its pressure when saturated, and becomes what is known as superheated steam.

All of the energy received by the steam in the process of superheating is available for power purposes. The heat required for superheating comes, of course, from the coal pile, but its cost in this respect is returned many times over by reason of the fact that the losses of twenty to thirty per cent. incidental to the phenomenon of cylinder condensation can be almost entirely avoided by moderately superheating the steam before it goes to the engine cylinders.

While what are called separately fired superheaters are to a very small extent used, superheaters can be obtained which are essentially a part of the boiler, utilizing the same furnace gases on their progress through the boiler. That a fuel saving of 10 to 20 per cent. can be obtained by the use of superheated steam is a well proven fact, and most large plants in course of construction are to-day designed for using it.

Packings and lubricants suitable for super-heated steam can be had, and the most important increase in engine efficiency during the last twenty years has been the very extensive adoption of the use of superheated steam. One pound of coal per indicated horse-power on daily average running is quite within the range of possibilities of the near future.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and fortieth regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's House, 410 Penn avenue, Pittsburg, Pa., Tuesday evening, December 15, 1903, at 8.15 o'clock. First Vice-President James M. Camp in the chair, and 128 members and visitors present.

The minutes of the preceding meeting were read and approved.

The Board of Directors reported that they have passed favorably on the following applications for membership, and present same to the Society for action:

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
WILLIAM O. ABBOTT,	Draftsman with W. G. Wilkins Co., Westinghouse Bldg. Pittsburg, Pa. h., 6311 Marchand St., Pittsburg, Pa.	W. M. Judd, J. F. Kuntz, L. B. Blum.
EDWARD C. BAKER,	Civil Engineer, with Elliott & Baton, 320 Fourth Ave., Pittsburgh, Pa. h., 318 Sycamore St., Pittsburg, Pa.	S. P. Cobb, J. P. Elliott, C. W. Ridinger.
HENRY C. BAKER,	Electric Engineer with Crocker-Wheeler Co., 607 Empire Bldg., Pittsburg, Pa.	W. Schmidt, W. G. Wilkins, W. M. Judd.
GUSTAV BERENTSEN,	Chief Draftsman, Westinghouse Electric & Mfg. Co., East Pittsburg, Pa.	N. W. Storer, C. F. Scott, P. M. Lincoln.
HARRY P. CROSBY,	Mechanical Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. h., 805 Walnut St. Wilkinsburg, Pa.	N. W. Storer, W. A. Dick, R. S. Feicht.
EDWARD H. DEWSON,	Chief Engineer, Westinghouse Traction Brake Co., Wilmerding Pa. h., 129 Gordon St., Edgewood Park, Pa.	C. F. Scott, G. S. Davison, E. M. Herr.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
SAMUEL F. HERR,	Draftsman, Heyl & Patterson. h., Aspinwall, Pa.	M. Rogaliner, E. J. Mason, W. H. Cornell.
AUGUSTINE L. LEE,	Structural Engineer, for McClintic-Marshall Construction Co., Rankin, Pa. h., 7618 Westmoreland Ave., Swissvale, Pa.	M. Rogaliner, A. M. Acklin, E. J. Mason.
CHESTER B. MILLS,	Mechanical Draftsman, with Westinghouse Electric & Mfg. Co. h., 1141 South Ave. Wilkinsburg, Pa.	N. W. Storer, W. A. Dick, S. M. Kintner.
WM. M. PARKER,	Engineer and Secretary, Wisconsin Graphite Co. h., P. O. Box 988, Pittsburg, Pa.	Wm. Metcalf, C. Parkin, S. M. Kintner.
J. LEE RODGERS,	Secretary and Chief Engineer, Pittsburg Gauge & Supply Co. 309 Water St., Pittsburg, Pa.	W. G. Wilkins, W. M. Judd, J. F. Kuntz.
MARCUS A. SMITH,	Estimating Engineer, Blair & Gazzam, 3d Ave. and Ferry St., Pittsburg, Pa. h., 6349 Marchand St., Pittsburg, Pa.	E. K. Morse, E. Swensson, W. H. Smith.
FREDERICK W. WINTER,	Solicitor of Patents, and Attorney-at-Law with practice in patent cases exclusively. 1202 Frick Bldg., Pittsburg, Pa.	J. I. Kay, A. Stucki, C. W. Ridinger.

Voted that the Secretary cast a ballot electing these gentlemen to membership.

MR. CAMP—In June of this year Mr. Albree, our President, had to make a hurried trip to Europe for his health, and it is with considerable sorrow that I have to announce that he came back and was immediately ordered away again by his physician. He is now on his way to Africa. We hope that he will return to us in good health later on. We will now have the report of the Nominating Committee.

The Nominating Committee report the following nominations for officers for the ensuing year, beginning January 7, 1903: President, one year, J. M. Camp; First Vice-President, S. Diescher; Second Vice-President, G. E. Flanagan; Treasurer, A. E.

Frost; Secretary, C. W. Ridinger; Director, two years, Willis Whited and J. K. Lyons.

MR. CAMP—These nominations are to be voted on at the annual meeting in January. If there are any other nominations they can be proposed to-night. The Auditing Committee is composed of F. V. McMullin, T. J. Wilkerson and Wilbur Altman, who are to go over the accounts of the Treasurer and report at the annual meeting.

Mr. Beutner then read the paper of the evening on "The Manufacture of Welded Pipe." Mr. Beutner reads paper, illustrating it with sketches and stereopticon views of drawings and machinery, etc.

THE MANUFACTURE OF WELDED PIPE.

BY VICTOR BEUTNER.

The reading of a paper before a society which, like our Western Engineers' Society, is composed of members of all the various branches of our profession involves a great difficulty. Such paper must either treat its subject in a general—I might say—popular scientific way, to be interesting to the majority of the members, or it must contain information as to real innovations and improvements above and beyond the present state of the art, in order to tickle the palate of the connoisseur.

In the first place, it will appear shallow, and commonplace to the inner circle, and in the second case, it will be very dull and even unintelligible to the majority, who usually have troubles of their own in their own specialties.

There are, however, very few engineers, who have become familiar with the subject of my present talk, the manufacture of welded pipe. Ever since pipe has been made the idea has prevailed that the various processes employed were quite secret and the manufacturers naturally have spread this conception to the best of their ability. The machinery and the methods employed were intrinsically their own, developed on lines quite different in each case. Access to the mills is absolutely denied, and the whole thing is shrouded in mystery. Even the few engineers, who have ridden the goat, are usually retained by the larger tube interests, and are, therefore, bound to secrecy. As a consequence there is no literature on this subject. The Britannica, or the large handbooks on iron and steel like Ledebur or Percy Wedding, do not even mention the manufacture of pipe, and a special treatise on the subject does not exist to my knowledge.

The manufacture of seamless tube fares somewhat better,

since the numerous patent papers contain quite some information. Therefore, whatever shortcomings this paper might have, it escapes the usual fate of scientific papers, which might be well worthy of being printed, but which very often have been printed before.

The earliest method of manufacturing tubes was the method employed by gunsmiths ever since the invention of firearms, until the first quarter of the last century. A piece of flat iron is bent around a mandrel, and the overlapping edges are brought to a welding heat, a few inches at a time, and welded by blows of a hammer. For the hand hammer of the earlier smiths a helve or trip hammer was substituted.

When with the introduction of gas and steam the demand for tubes increased greatly, it became necessary to insist on a greater uniformity than could be obtained in hand welding, and in 1824, James Russel passed the hand welded tubes through a set of rolls and over a mandrel, thereby obtaining the proper inside and outside diameter of the tube. James Russel further established the fact, that a sufficiently strong joint can be obtained by forcing the ends of the skelp against each other, instead of overlapping them, as had always been done previously. This fact led directly to the introductions of the new methods of butt welding pipe, which are still in use in practically their original form. James Whitehouse, in 1825, took out a patent covering the following process: A piece of skelp of suitable width is bent until the two edges nearly meet. One-half of this bent skelp is inserted in a furnace and brought to welding heat. The cold end is fastened in a suitable manner to the traveling chain of a draw-bench. The two halves of a ring-shaped die are closed together by a pressure screw, the chain is started and the heated portion of the skelp drawn through the die. The diameter of this die is a trifle smaller than the outside diameter of the skelp and the pressure exerted is sufficient to close the joint of the skelp by welding the edges together. Then the half-welded pipe is reversed and the other end finished in the same way. The pressure screw used to force the two halves of the die together soon proved far too

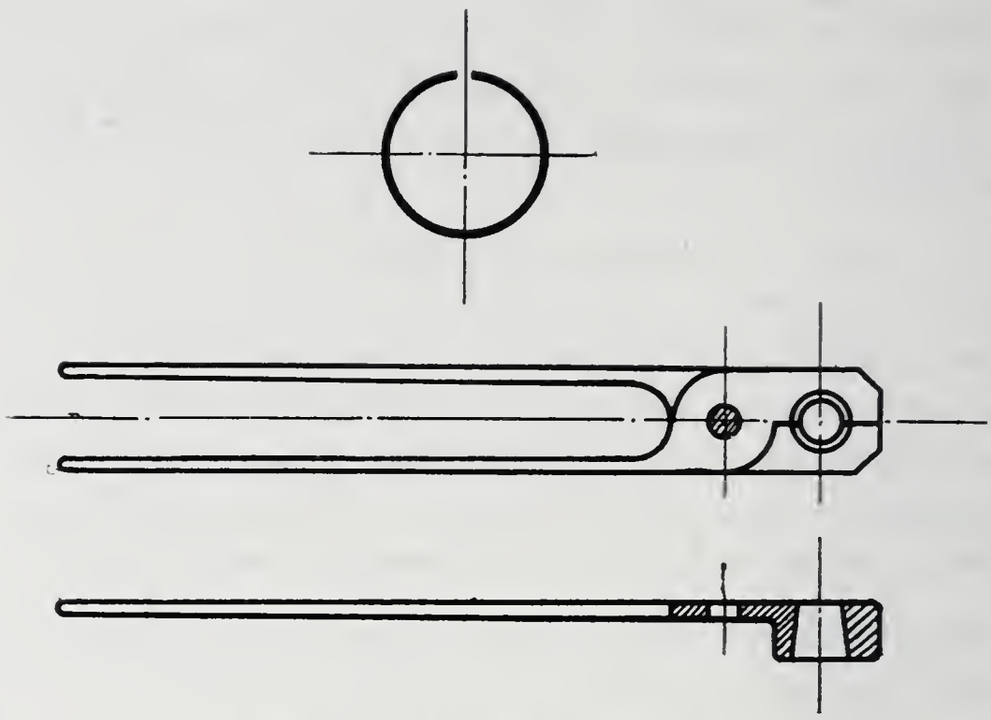


Fig. 1. The Tong Process.

slow and tongs were used, shaped as shown in figure No. 1, the jaws of which form the dies and can be quickly opened and closed. The draw-bench is provided with a steadying rest, against which the tongs are rested while the tube is drawn through.

Very soon a very important improvement was made in the manufacture of butt welded pipe. A solid die, usually called a bell, was employed and it was found possible to bend and weld the skelp in one operation, by first clipping the corners of the skelp, and by employing suitably constructed tongs, which gripped the skelp very firmly, yet were small in diameter and could pass through the opening of the bell, figure No. 2. This method—usually called the bell weld method—has found a very large field, owing to its simplicity and cheapness. The strength of such butt welded joint is also very remarkable. I have seen 1″ pipe made by this method, tested to 1,000 pounds per square inch, hydrostatic pressure, and the thickness of metal of 1″ standard pipe is little more than $\frac{1}{8}$″. The limitations of the bell weld methods are self evident. When either a very great resistance to inside pressure is required, or when it is essential to keep the thickness of metal

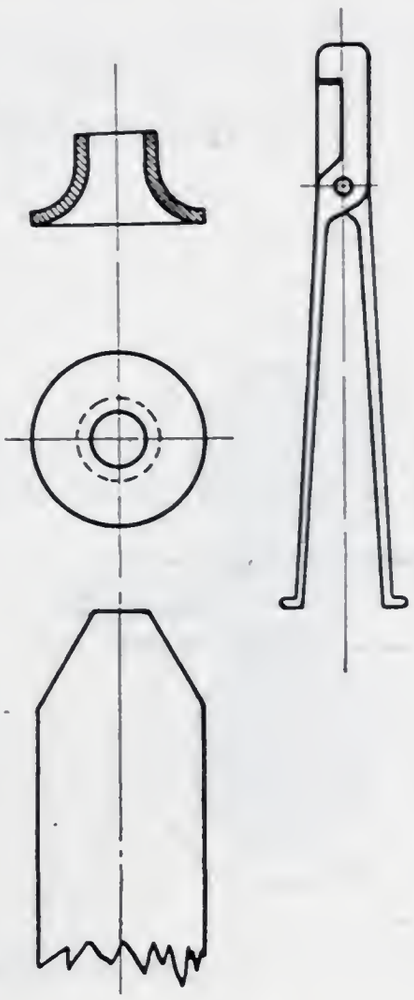


Fig. 2. The Bell Weld Process.

down, it is impracticable. The skelp of large pipes has the tendency to collapse, instead of filling the bell, and, although I have seen 4″ pipe made successfully, the usual commercial limit for this process is 2″, or at most 2½″.

The smaller sizes, say below ⅜″, present another obstacle, since the gripping tongs must pass through an opening of the bell, which is too small to allow of their proper strength of construction. In this case, the tong process described above is employed, while in all the other cases the lap weld method must be resorted to.

This method dates back in all its essential features to about 1840, when it appears that both the Russels and a man named Martin Jones took out patents covering same. In this method, the skelp, previously bent in a manner that one edge overlaps the other, is heated to a welding heat, and immediate-

ly passed through the grooves of rolls and over a mandrel. Through the presure between the upper roll and mandrel, usually called ball, the two overlapping edges are united, figure No. 3.

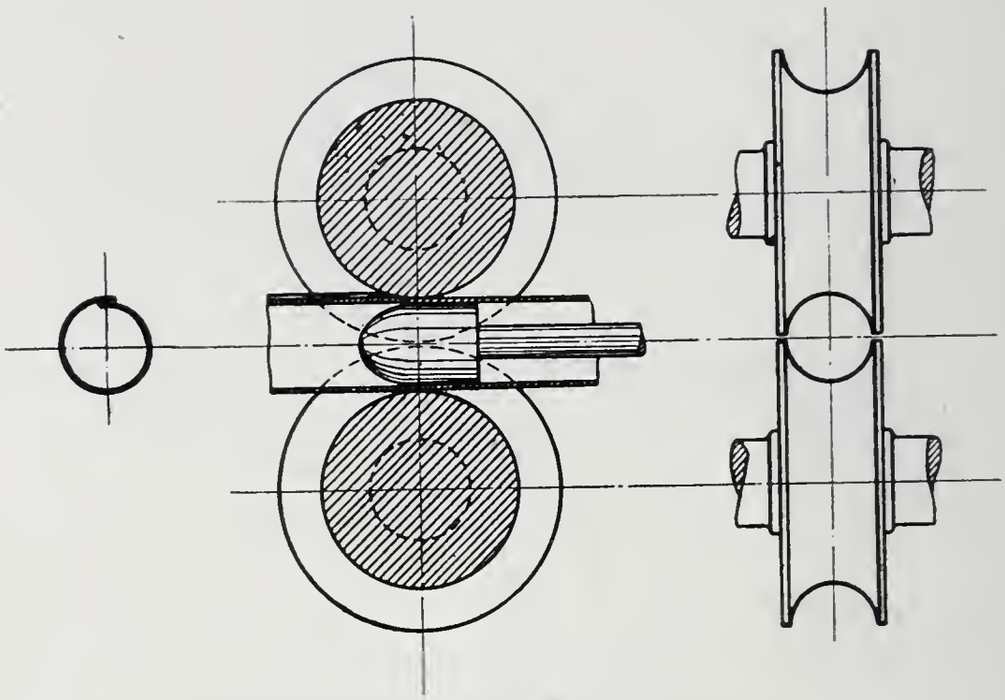


Fig. 3. The Lap Weld Process.

Although not altogether within the scope of this talk, it might prove interesting to most of you to have the most important method of manufacturing seamless tubes shortly discussed.

The oldest and simplest method is the rolling, or drawing out of a billet, which has been previously pierced by forcing a punch through its center while in a red hot state. Another method is illustrated by figure No. 4. Through a number of successive operations a flat sheet of metal is cupped, the depth of this cup increasing with each operation. Lastly the bottom is cut off and, if desired, the tube may be finished by drawing. A patent taken out some fifteen years ago, provides for the casting of small ingots with a core of powdered refractory material, which hollow ingot is again finished as above. Quite a startling innovation, however, was embodied in the principle of diagonal rolling, as covered by a number of patents awarded to the brothers Mannesman in 1885 and 1886. This

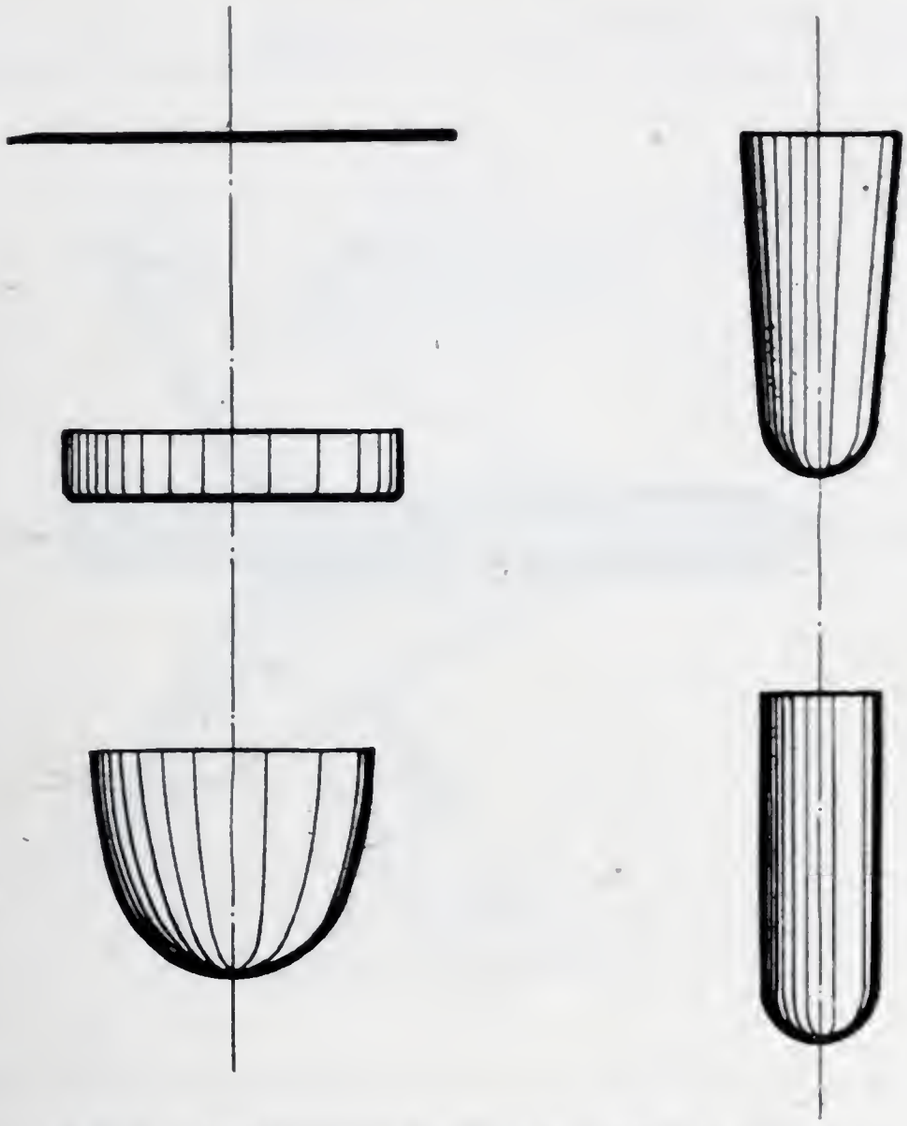


Fig. 4. The Cupping Process for Seamless Tubes.

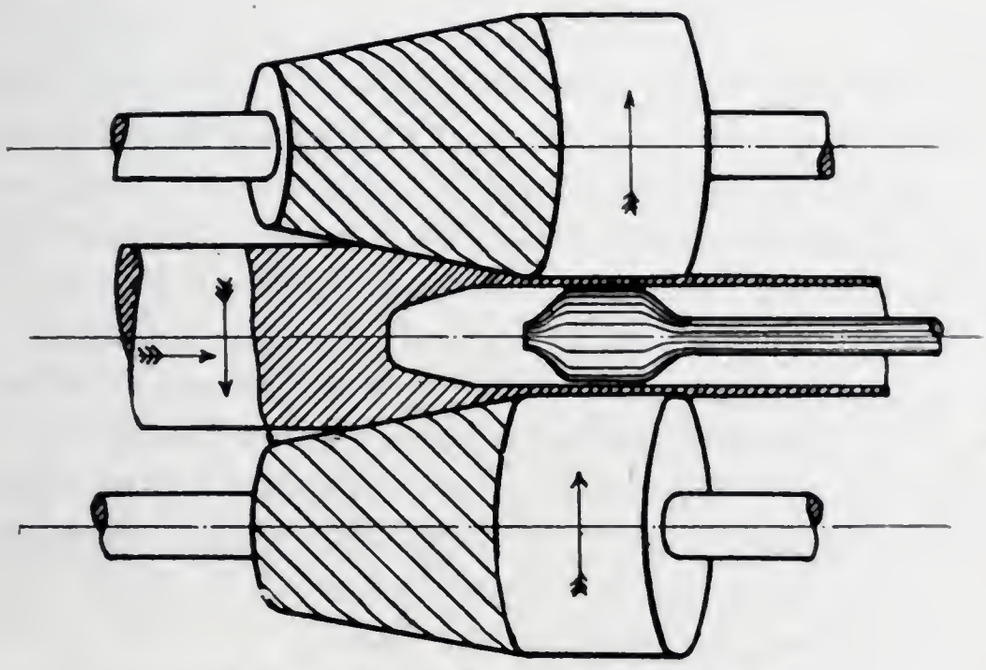


Fig. 5. The Mannesmann Process.

principle can be carried out in a number of ways, of which figure No. 5 and figure No. 6 are representative instances.

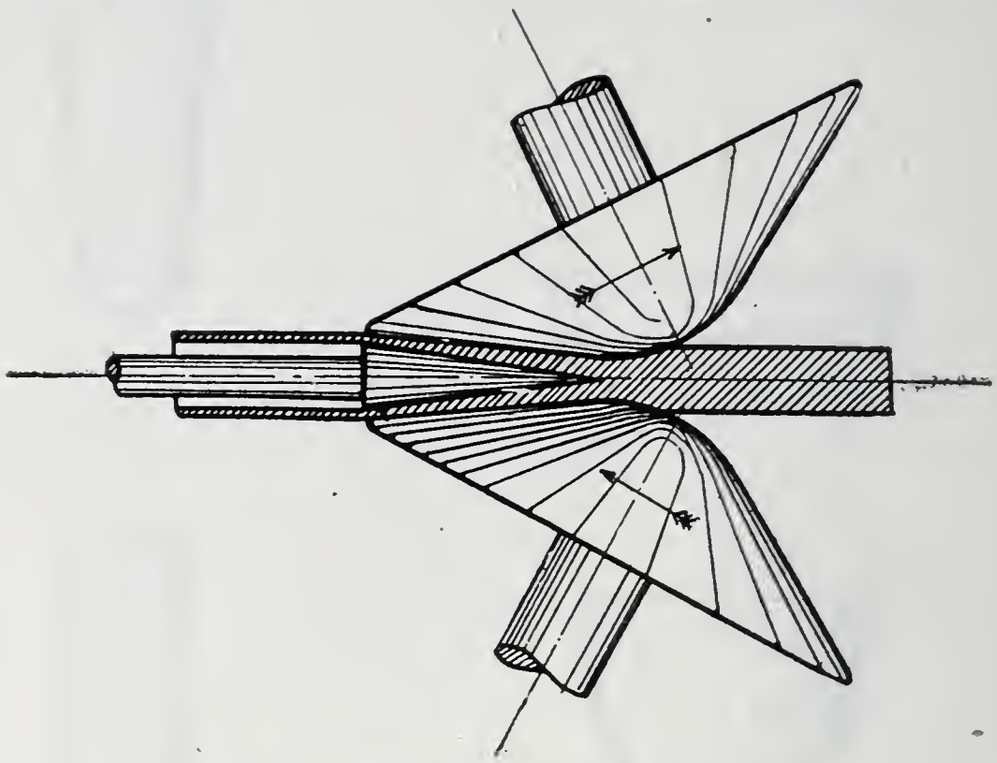


Fig. 6. The Mannesmann Process.

It can be readily seen from the sketches, that the rolls impart a rotary or whirling and a forward motion to the piece. In the arrangement shown in figure No. 4 this forward motion is caused by the inclination of the axis of the conical rolls in relation to each other, while in figure No. 6 the rolled piece is introduced not quite on a line with the axis of the mushroom rolls. An altogether satisfactory explanation for the remarkable results of this method is hard to give. It seems that the material, instead of flowing in a longitudinal direction, as in the ordinary rolling, has a tendency to flow outwards toward its circumference, owing to the rotary motion, a distinct displacement of the fibre taking place. This fact is shown clearly in figure No. 6, where the resulting tube has a larger diameter than the original billet. The mandrel shown in both cases has nothing to do with the formation of the hole, and only serves to smooth the inside of the tubes.

In the Stiefel process patented in '95, and shown on figure

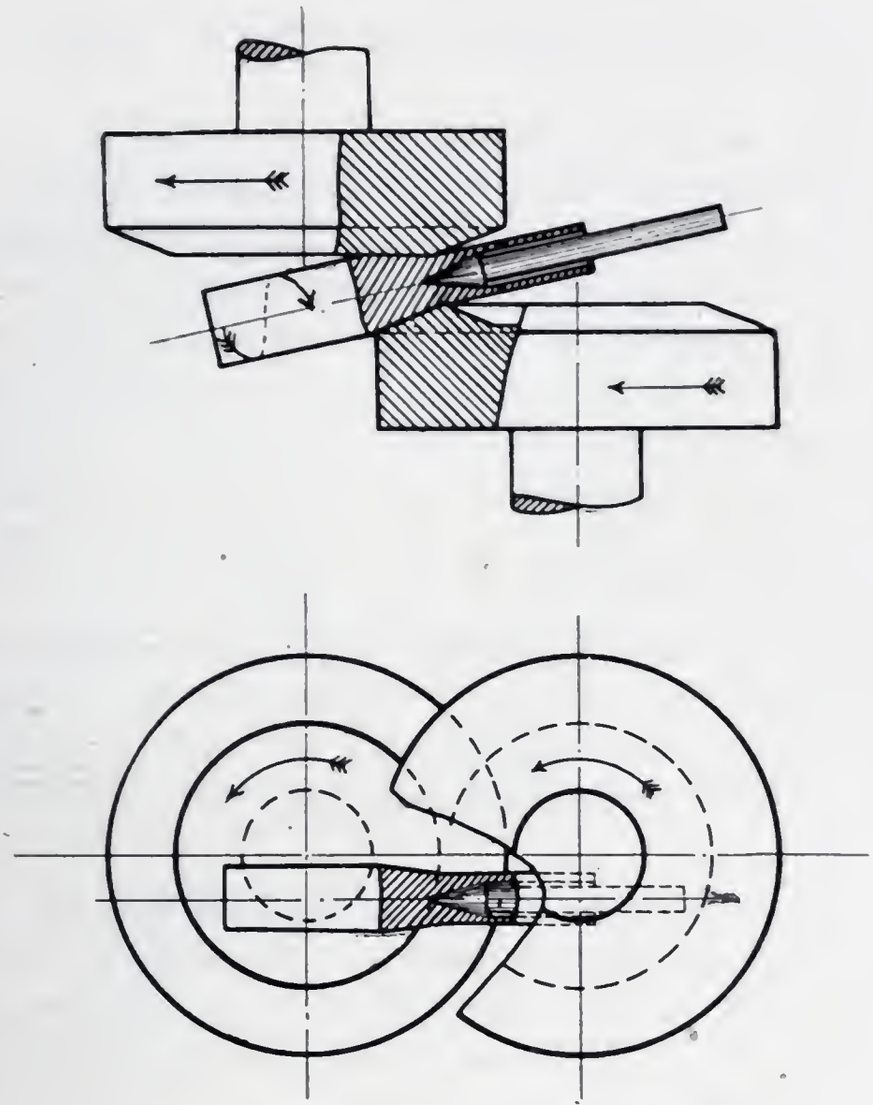


Fig. 7. The Stiefel Process.

No. 7, a heated billet is passed between the faces of two parallel discs, which impart to it a rotary and a forward motion, forcing it thereby against and over a piercing mandrel. The working faces are shaped in such a manner as to cause a uniform speed of rotation and thus the parallel longitudinal arrangement of the fibres is not disturbed.

In the Ehrhard process, a piercing bar is forced into a solid billet, the cross section of which corresponds with the area of the tube to be produced. This billet heated to white heat is placed in a form, which corresponds to the outer shape of the tube. The difference of the area of this form and of the area of the billet must be equal to the area of the piercing bar. The metal forced from its center flows to the outside, taking up the space between the original billet and the form,

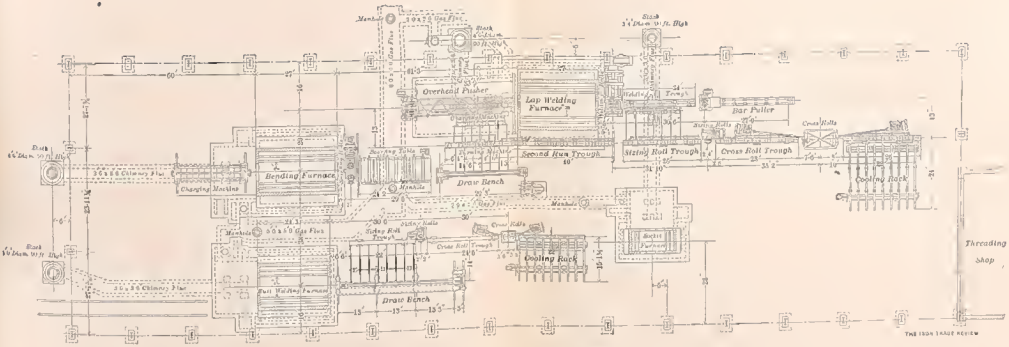
which is equal to the amount of material displaced by the piercing bar.

It might not be amiss to say a few words as to the comparative merits of the seamless drawn and the ordinary welded pipe. The first certainly presents a highly interesting subject from a technical standpoint, and through the ample discussion of the various methods in scientific bodies and the advertising derived from its use for boilers, or other tubular appliances, the seamless tube has gained quite a notoriety. I am prepared, however, to say—although I was not able to procure exact statistical figures—that of all the wrought pipe manufactured to-day 95% and probably even considerably more, is made by either the butt or lap weld method. The great difference in the cost of manufacture, and the fact that although seamless pipe might be better, the ordinary welded pipe is amply good enough for all but exceptional cases, are the obvious reasons for this fact.

The strips of wrought iron or steel used in the manufacture of welded pipe is called skelp. Its width is equal to the outside diameter of the desired pipe, plus a trifle for compressing the edges in butt weld, or plus the necessary allowance for a lap in lap welded pipe.

The smaller sizes of skelp are rolled in grooves in three-high skelp mills, differing little from the ordinary bar mills; the larger sizes in universal mills, with two plain horizontal and four vertical rolls, and for the largest size plate mills are used, and the rolled product sheared to the proper width.

In the beginning, it was thought possible to use only iron skelp for the manufacture of welded pipe, that is, skelp rolled from piled strips of muckbar, made by the puddling process. When, with the introduction of the Bessemer and open hearth process, steel found a daily growing field, and when the metallurgist became acquainted with its peculiarities, it became a tempting proposition to use steel possessing the proper chemical and physical properties for making pipe, and a former member of this society, the late T. J. Bray, was one of the very first who successfully solved this problem in the Riverside



General Layout of Modern Pipe Mill.

Tube Works, which at that time he managed. To-day by far the greater portion of welded pipe is made of steel, and even the difficulties which presented themselves in threading the soft basic open hearth steel are being rapidly overcome. A representative analysis of the steel used for skelp ought to show about

Carbon	.05
Manganese	.36
Phosphorus	.1
Sulphur	.05
Silicon	.02

These properties, however, might be materially modified by individual experience or preference.

Generally speaking, steel presents less difficulties in manufacturing than wrought iron being much "cleaner" to handle and furnishes a more uniform and reliable product. The only exception is the well-known power of resistance of pure wrought iron to the influence of rain or other atmospheric moisture and to the corrosion by the soil, if exposed to either, without protection. In such case the wrought iron pipe will outlast the steel pipe nearly three times.

In the designing of pipe mills, the same principles which govern the design of every steel plant, for that matter, every manufacturing plant, must be observed.

The product ought to pass through the various machines in a logical manner, as each operation is to be consecutively performed, without ever doubling back on its own track, or interrupting the continuous progress. If the last operation is to be performed with a certain speed, which will determine the output of the mill, the machines preceding ought to perform the work from step to step with greater speed, to provide a safe guard against stopping the whole chain of operations, if one of the initial appliances should be temporarily stopped.

The times when pipe mills were put in cheap, tumble-down board structures have passed, and the steel frame building, either with brick filler walls, or with corrugated sheet covering, has been adopted universally.

Very often a traveling crane commands the total space occupied by the rolling machinery, to be used for changing rolls, or to repair quickly break-downs, and if such crane can shorten the delays only one hour per week, it will have paid for itself in incredibly short time. The means for providing light and ventilation must be carefully considered. The work around the furnaces is trying and hot, and even with artificial fan ventilation and in modern mills spell hands must be secured for some of these furnace men, during the warm season. In older mills, some of these men only work fifteen minutes and rest thirty minutes. The upper end of the building must contain ample storage room for skelp conveniently situated to the charging end of the furnaces, and, indeed, unless your pipe mill is directly connected with skelp mills, which can be operated to suit your requirements, this skelp storage ought to be very ample.

It is self-evident, that in order to obtain the best results, a mill must be run as long as possible on one size of pipe, and the changes from one size to the other ought to be made gradually, beginning from the smallest, slowly increasing to the largest size within the capacity of the mill and then slowly stepping down again.

An electric traveling crane, usually running crosswise through the building, and often extending into wings, unloads the skelp, stores it and delivers it to the furnaces. Where the skelp is stored outside or in large sheds provided only for this purpose, a locomotive crane has been employed with good success.

Since both methods of manufacturing pipe, treated in this talk, depend upon the successful heating of the skelp to a temperature at which the edges can readily be united or welded, the apparatus to produce this heat—the furnace equipment—occupies a very prominent position in the design of a pipe mill.

The development of the pipe welding furnace has been about the same as that of the metallurgical furnace in general. From the open smith fire, sprung short coal fired heating furnace, which grew longitudinally until it could receive the full length of the pipe. One whole side of it was occupied by the

fire-box, from which the flame played across the hearth into the flues on the other side, to be drawn into the stack. In the anthracite region such furnaces are still in use in mills, where owing to their connection with mines, anthracite in any quantities, is considered economical. Some of the mills in the Pittsburgh district employed practically the same type of furnace, only using natural gas and substituting a number of burners for the fire-boxes. The one great step forward in the construction of welding furnaces, however, came shortly after 1861, when Sir Wm. Siemens established the principle of regeneration and the gas-fired regenerative welding furnace is to-day universally used in pipe mill work.

Under regeneration, we understand the storing of waste heat of the escaping gases after combustion in the furnace and the utilizing of this stored heat to raise the temperature of gas and air before combustion. This is accomplished by passing the off-gases through chambers filled with brick checker work, by which a considerable amount of the heat of these gases is absorbed. After a certain time the operation of the furnace is "reversed" and air and gas passing through the heated chambers absorb the heat of the checker work, the off-gases in the meantime heating another set of chambers. This reversal is constantly kept up and the temperature of gas and air before combustion becomes very soon intense. A greater heat on the hearth of the furnace proper and great fuel economy are the natural consequences.

As shown, the operations of the regenerative furnace depend upon a gaseous fuel, and together with his furnace Siemens put the first gas producer upon the market. Generally speaking, the producer consists of a brick lined iron shell with suitable grates at the bottom for the admission of air either by natural draught, or, in all modern constructions, by steam blowers. The process is simple. After a producer is properly started, the carbon of the lower layers of coal is burned to carbon dioxide. This CO_2 rising through a layer of hot coal is reduced to carbon monoxide, while the water vapor caused by moisture or steam blast is decomposed by the incandescent carbon, forming carbon monoxide and hydrogen. To prevent

the escape of any gas during the cleaning of the fires, a water pan has been introduced, which effectually seals the bottom of the producer, the clinkers and ashes resting in this pan and being removed below the water level.

Producers are generally arranged in a row, with convenient provisions for the handling of the coal, which is supplied either by an elevated track, running parallel to the producer platform, or by overhead conveying machinery. The gas is collected in flues either overhead or underground and distributed to the furnaces. A good producer will gasify 7 tons of coal per day, giving in round numbers 1,000,000 cubic feet of gas. Producer gas consists of about

6 Carbon dioxide.
23 Carbon monoxide.
8 Hydrogen.
3 Methane.
60 Vitrogen.

and as a fair average 120 B.T.U. per cubic foot might be figured. Usually two producers are provided for one furnace.

In the Pittsburgh district natural gas is used extensively, which shows a much higher calorific value than producer gas, having a heat value of over 1,000 B.T.U. Natural gas is mostly composed of from 60% to 70% Methane or marsh gas (C.H.4) and of from 20% to 30% hydrogen, with smaller proportions of other hydrocarbons. Owing to the fact that the hydrocarbons are decomposed even in a moderate heat, precipitating solid carbon, natural gas is directly introduced into the furnace without being previously "regenerated."

Since Siemens built his first furnace many improvements have been made. The illustration, figure No. 8, shows an up-to-date welding furnace, embodying all these improvements. The regenerating chambers are situated below the furnace proper, the hearth being carried on a grill work of beams providing ample ventilation below. The air chambers each contain 1,000 cubic fect of checker work and the gas chambers $\frac{1}{4}$ less. The retaining walls around the chambers contain hollow spaces arranged to drain any moisture seeping through the ground to a sump, from where it can be removed. From the chambers, alternating air and gas ports lead into the furnace, each provided with

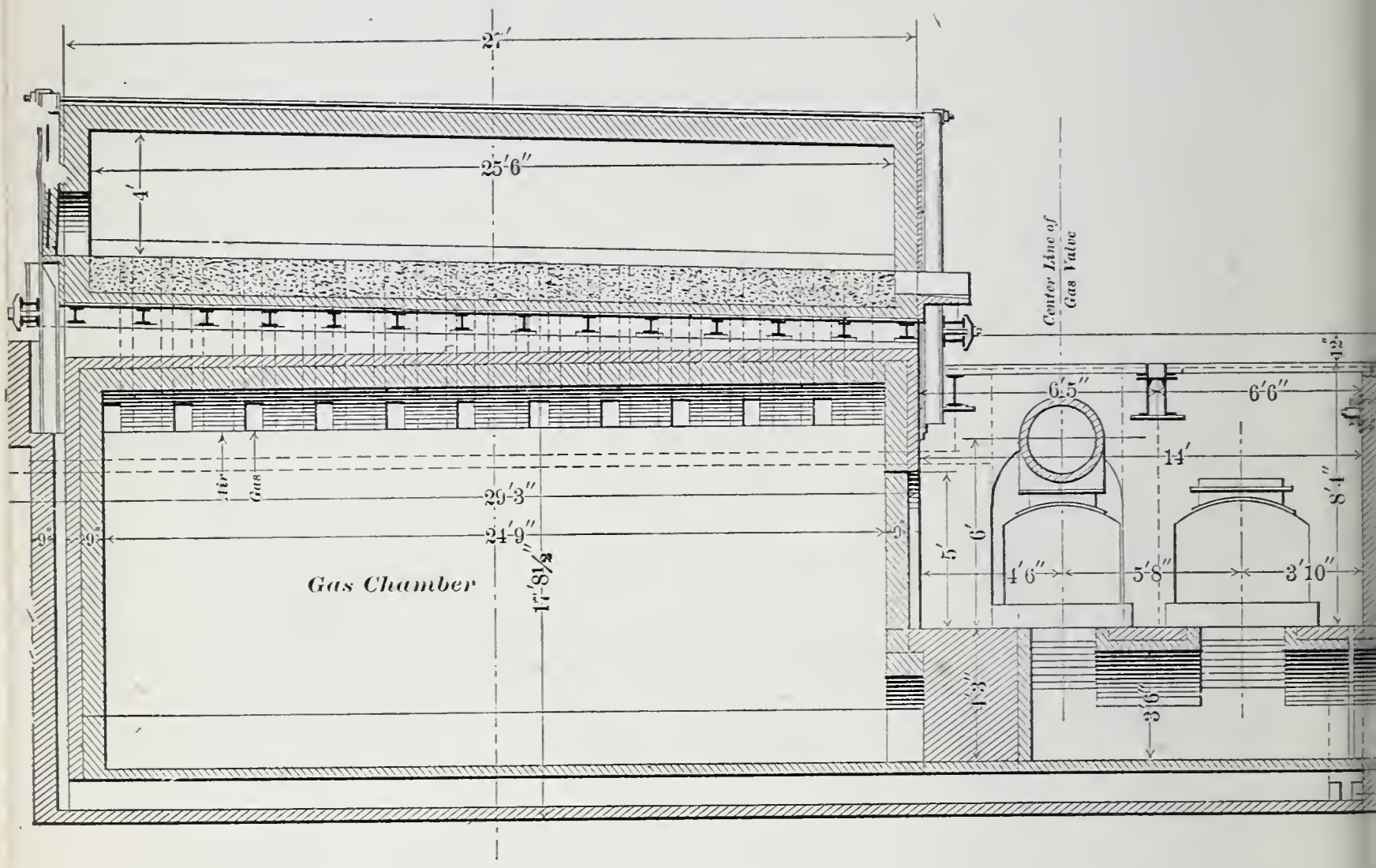
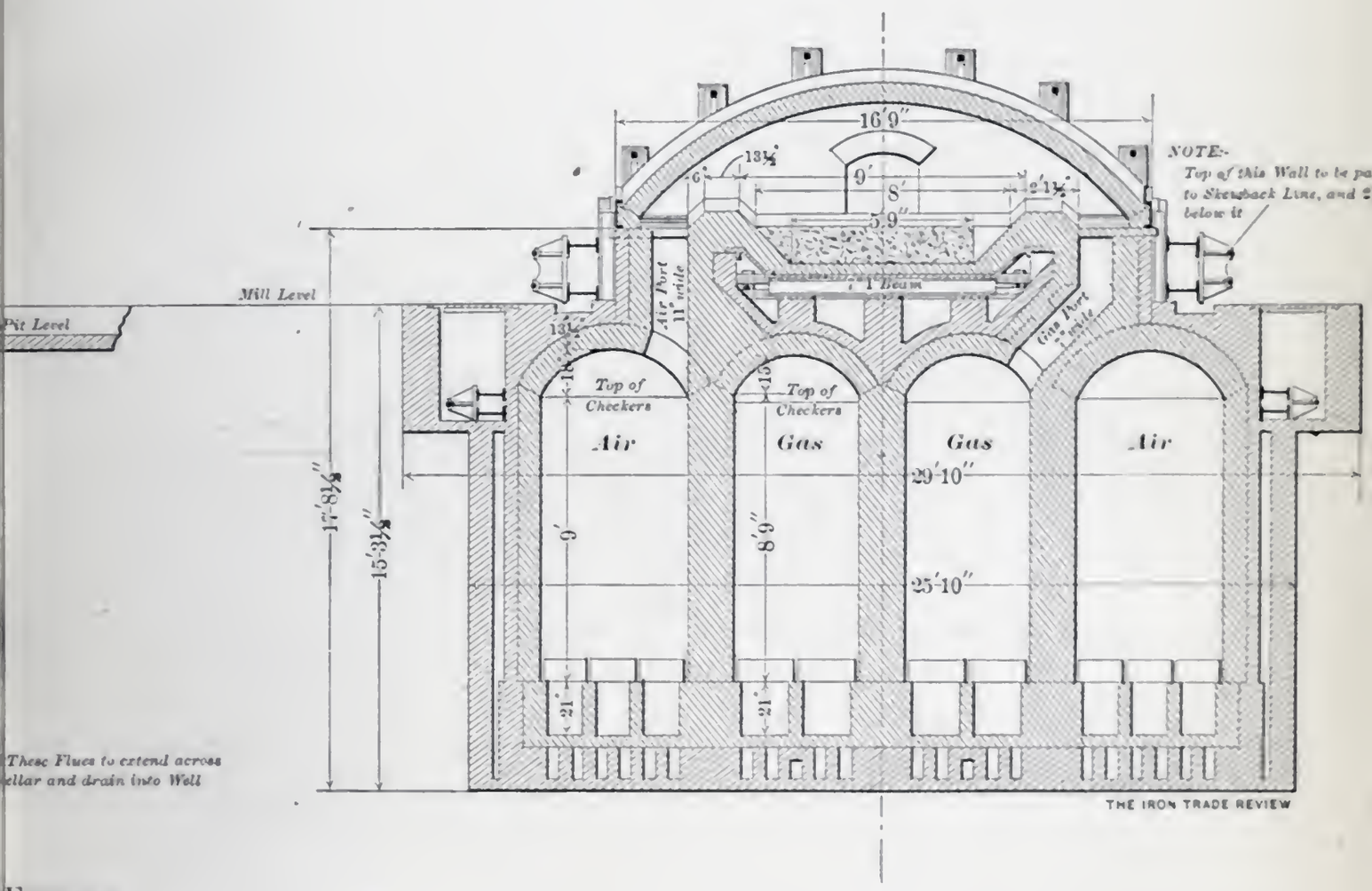

27′
25′6″
4′
Air
Gas
29′3″
24′9″
9″
9″
5″
Gas Chamber
17′8½″
Center Line of
Gas Valve
12″
6′5″
6′6″
14′
6′
5′
8′4″
4′6″
5′8″
3′10″
13″
36″

Fig. 8. W


16'9"
13½
6"
9'
8'
2'1½"
5'9"
NOTE:-
Top of this Wall to be pa
to Skewback Line, and 2'
below it
I Beam
Air Port
11" wide
Gas Port
11" wide
Mill Level
Pit Level
13½
18
15
Top of
Checkers
Top of
Checkers
Air
Gas
Gas
Air
29'10"
25'10"
17'8½"
15'3½"
9'
8'9"
21
21
These Flues to extend across
cellar and drain into Well
THE IRON TRADE REVIEW

Furnace.

means of individual regulation. The brickwork of the furnace proper is kept as thin as possible, utilizing the cooling effect of the air outside to preserve the masonry. To support this frail brickwork, an extensive system of braces or binders is provided and indeed a modern furnace is a permanent steel frame structure with fire-brick filler walls, which might be repaired, or replaced, whenever required. The construction of the reversing valves used for these and other Siemens furnaces, is well known. The original Siemens or Butterfly valve became invariably warped and permitted considerable leakage. The Forter Water Seal Valve has overcome this difficulty, and is to-day used with great success. A separate self-supporting steel plate stack of 100′ height by 4′ diameter is provided for each furnace.

The application of power to drive the various machines used in the manufacture of pipe has presented an interesting problem. A modern lap weld mill arranged to roll from 8″ to 16″ pipe contains no fewer than nineteen individual machines, requiring various horse-powers ranging from 5 to 300. Line shafting with belts or gears and an occasional isolated engine were first universally used. At the best, line shafts with hangers and belts and steam pipes are a nuisance in a rolling mill, and here they either occupied valuable space overhead, obstructing everything else, or had to be buried in ditches hard of access. The perfection of the electric motor of various systems solved this difficulty. The motor occupies little room, and is made now of approved design, in a great variety of sizes and the distribution of power is easily accomplished. The larger units of dynamos and engines required for generating the power, situated usually in a clean power station allow the use of better type of equipment, and therefore higher steam economy. It would lead us too far to discuss the various types of motors, but in all installations of pipe mills, with which the writer has been connected, the Westinghouse 3-phase A. C. Induction Type Motor has been used with perfect success. The absence of collectors, commutators and brushes and the heavy copper strip winding, together with its compact mechanical design, adopt this motor excedingly well to the rough work in pipe mills. The great fly-wheel effect of the larger

motors caused by the high speed and great weight of the revolving parts is of considerable benefit in cases where the work is done only for few consecutive seconds at the time. Variable speed is not required in pipe mill work, and, where necessary, the reversing of the motors can be readily effected by mechanical means. The difficulty to get several units of the dynamos to run "in step" has been successfully overcome.

We come now to a discussion of the machinery proper, which serves to convert a piece of skelp into a marketable tube. For the manufacturing of lap welded pipe, the principle of which was shortly set forth above, two furnaces are required, one to heat the flat skelp for the bending operation, and the other to heat the previously bent skelp to a welding heat. The skelp is charged into the first, or bending furnace, either in single strips, or in piles, until the hearth of 7′ or 8′ width, of the furnace, is covered. For this purpose a bench or table equipped with a chain running over sprocket wheels is used, upon which the skelp is deposited by the crane. The table has a lateral, or sidewise motion, which permits it to be placed opposite any point of the full width of the furnace hearth. A hook or pusher rod is dropped into the links of the traveling chain and the skelp shoved into the furnace. A longer rod is used in the same manner to push the heated skelp through the furnace into the scarfing rolls.

When the two overlapping edges of skelp are united by welding, it is evident that either an extra thickness of material on this joint must appear, or that the pressure between the welding rolls and the ball must become very severe. To avoid either disadvantage, the skelp is scarfed, that is, its edges are beveled off, thus allowing in the lap the same contact surface, but less material. Originally this scarfing was done by cutting on machines built somewhat like plate planers, but this method has been surpassed by the far simpler process of scarfing in the rolls. The drawing, figure No. 9, and the photograph, figure No. 10, show such scarfing rolls mounted again on wheels for lateral motion to suit the situation of the skelp in the furnace. The rolls have a bevelled collar on opposite sides, the bevelled surface of which forms the scarf, and can be laterally

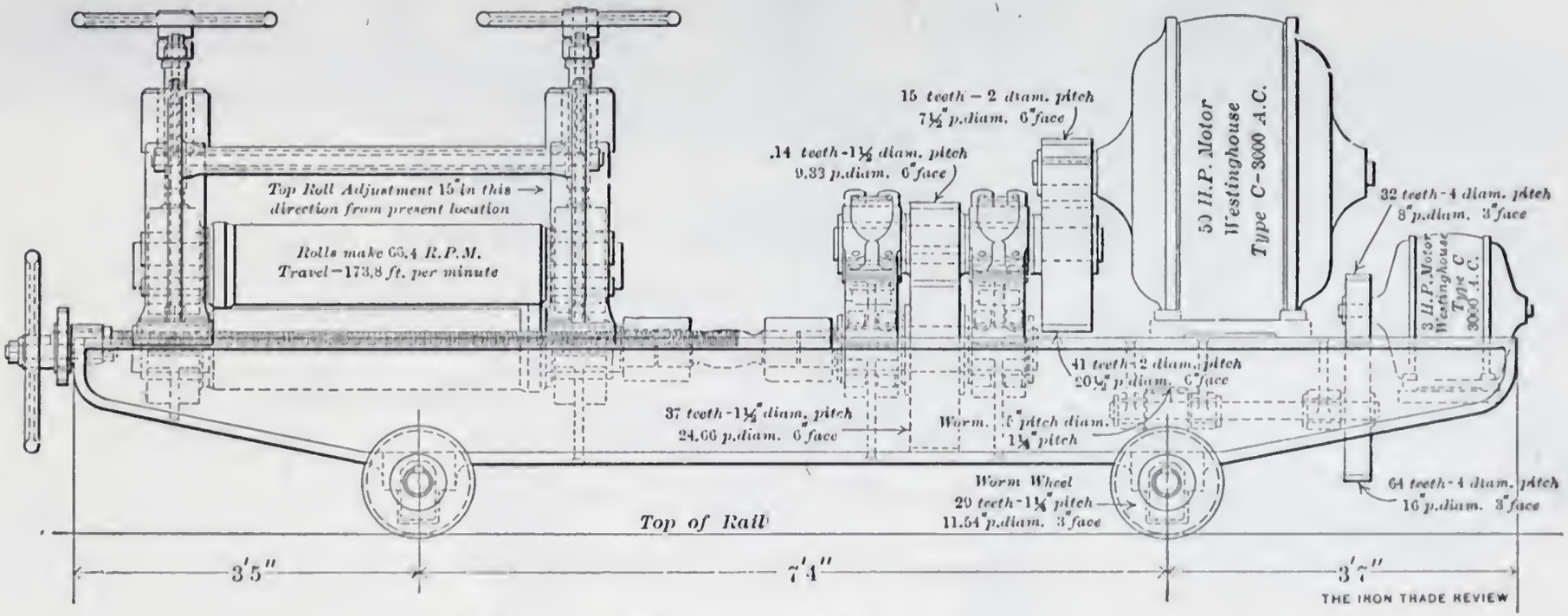


Fig. 9. Scarfing Rolls.

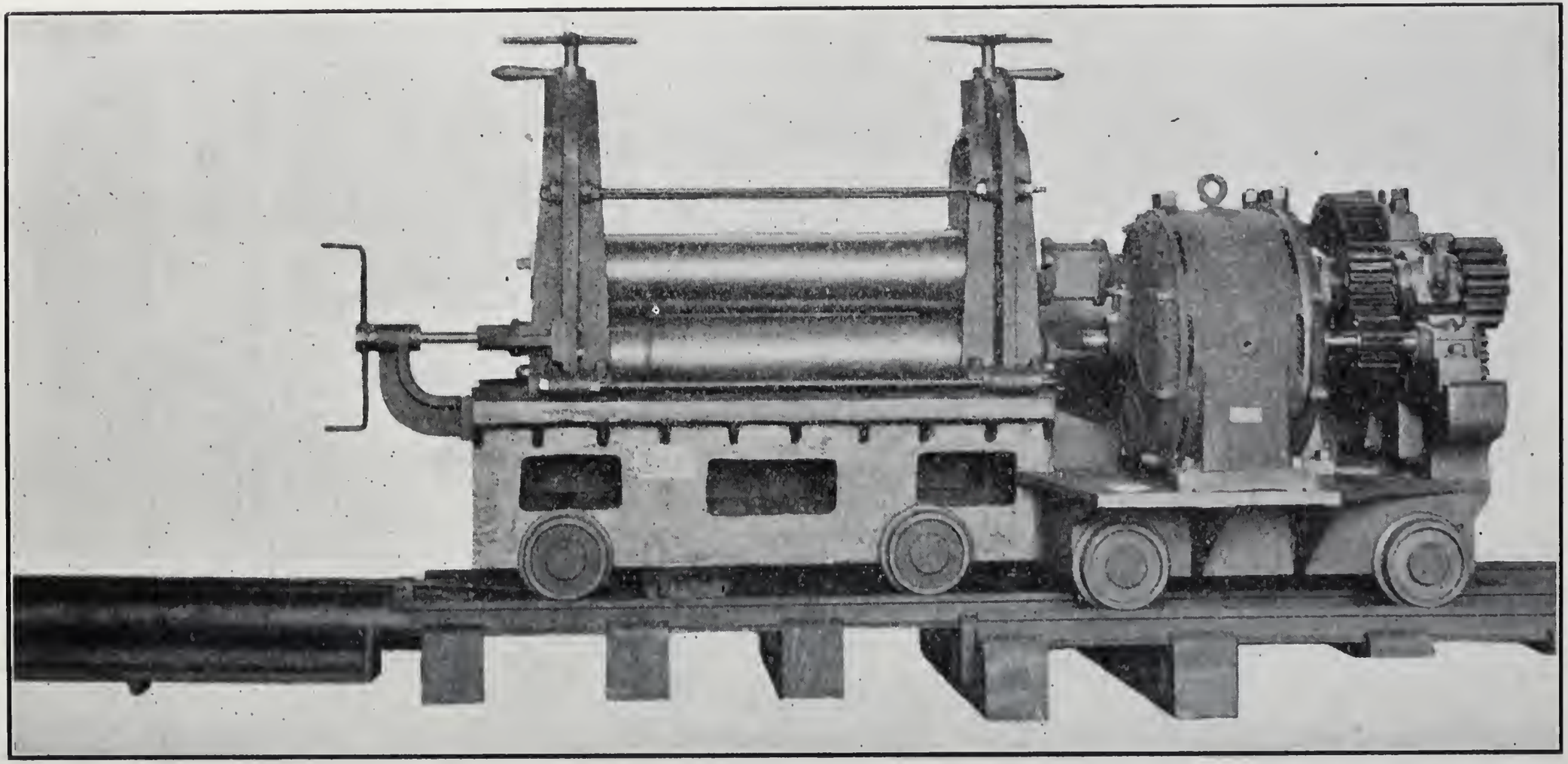


Fig. 10. Movable Motor-Driven Scarfing Rolls.

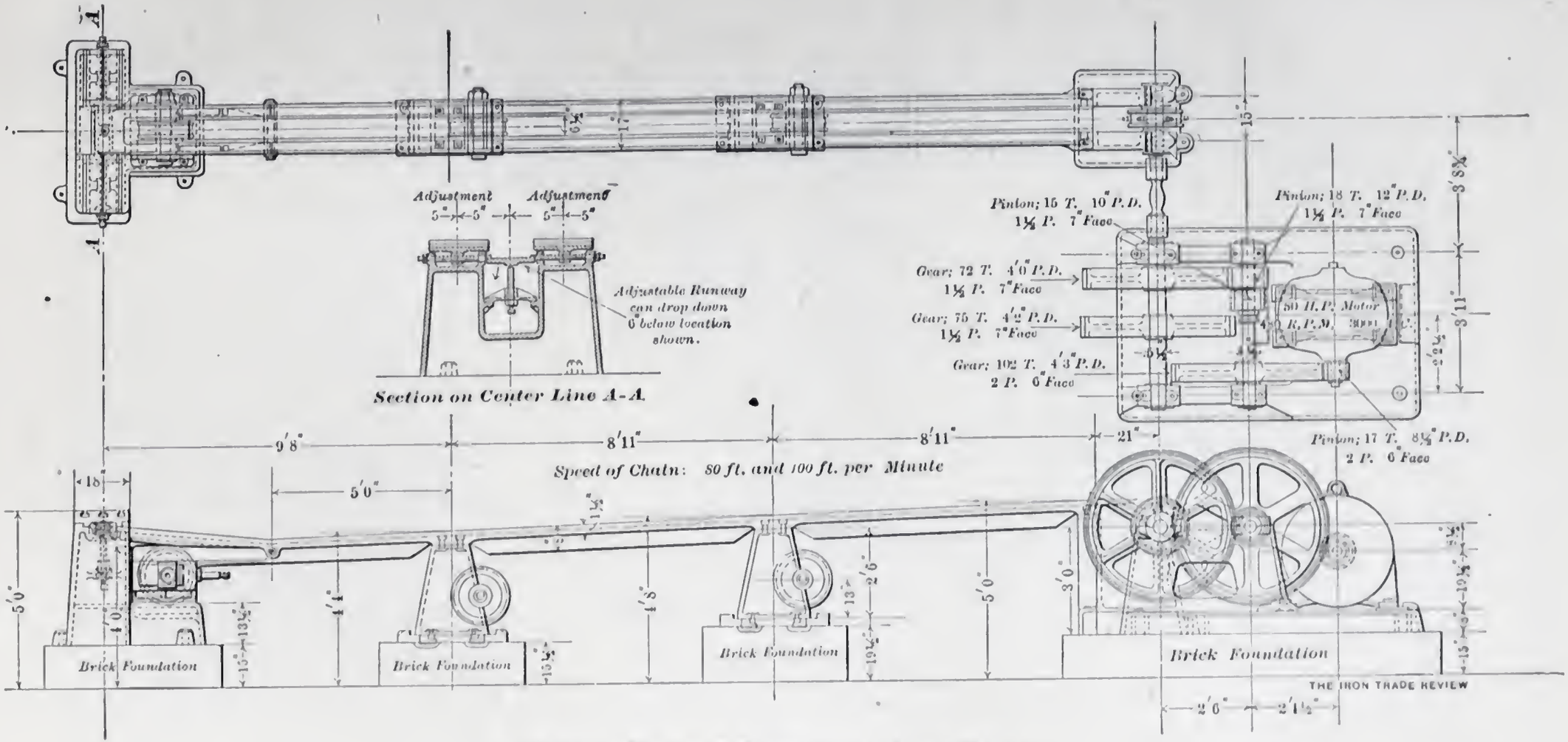


Fig 11. Plan and Elevation of Draw Bench.

adjusted to suit the distance between collars to the width of the skelp. A scarfing table receives the scarfed skelp and transfers it sidewise until on line with the bending bench, when it feeds it forward into the bending die. The bending die is a large cast iron funnel-shaped affair into which the skelp is drawn by strong gripping tongs, which are hooked to the endless chain of a draw bench. The construction of the draw bench can be readily seen from the accompanying drawing, figure No. 11. To avoid the lateral transfer of the skelp on the scarfing table, the scarfing rolls, scarfing table and draw bench are in some mills mounted on one carriage. The largest size skelp, which can be successfully bent in dies without collapsing, is 12″ pipe skelp, and few mills attempt to bend above 10″. Where larger sizes are desired—and we have to-day two mills in operation, which can roll 30″ pipe, and several more in course of construction—the skelp has to be bent in rolls, designed in general on the same lines as boiler bending rolls, but lately equipped with power feed, hydraulic pressure, and other improvements to operate same quickly and positively. Such rolls are usually situated parallel to the scarfing table, the lateral motion of which is increased sufficiently to drop the scarfed skelp sidewise between these rolls. Large sized skelp is usually tacked together by a rivet or two on each end to keep it from collapsing in the welding furnace.

The bent skelp is deposited on skids, conveniently located to the welding pit, as the depression on the charging side of the welding furnace is usually called. In this pit the hardest work and the work requiring the greatest skill is performed. The welder and his assistants charge the skelp, which has gone immediately before through the described process of bending, and is still red hot, through openings in the end walls into the furnace. The hearth of the welding furnace is slightly inclined towards the welding pit to cause the cinder to run off freely. The center of the hearth, which is in later furnaces over 7′ wide is occupied by the gutter in which the pipe, which is ready for the welding, rests. The charging openings are on both sides of the gutter, and the charged skelp is rolled over several times to expose all parts to the heat before it

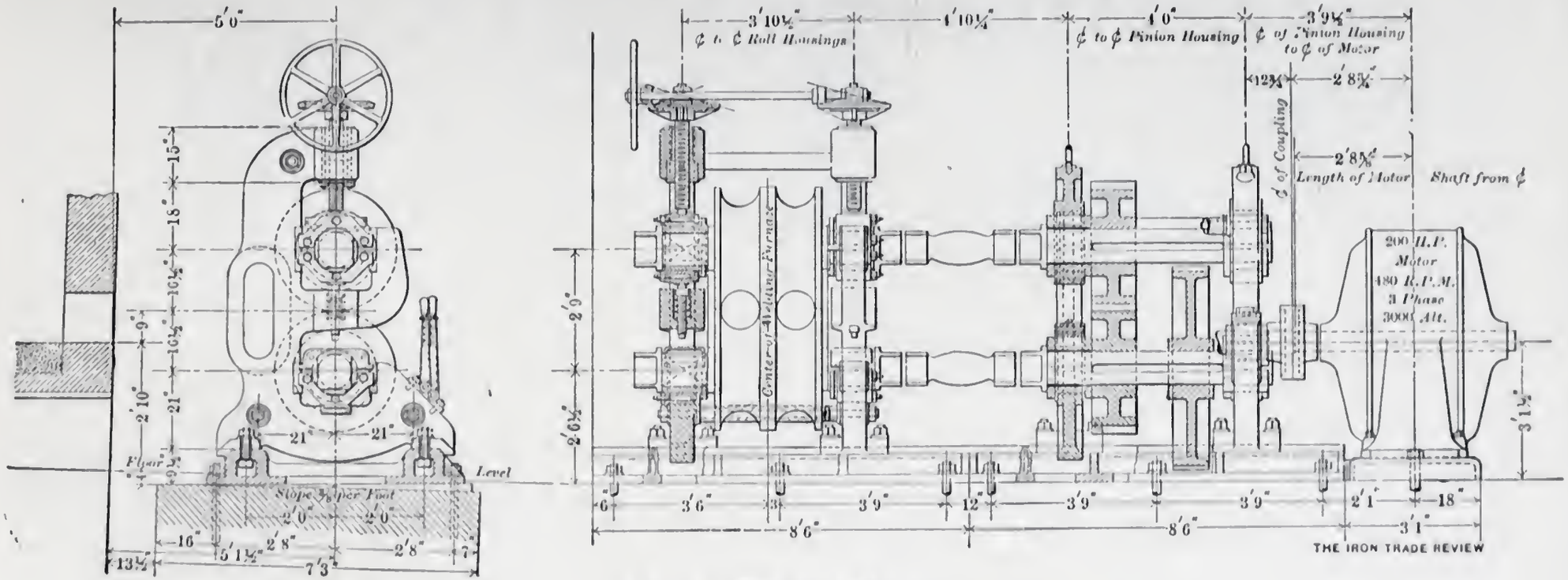


Fig. 12. Welding Machine.

reaches the gutter, when the overlapping edges must be on top. According to the sizes of the pipe and the skill of the welder 2, 3 or 5 skelps are simultaneously in the furnace. As soon as the skelp in the gutter has acquired welding temperature, it is pushed out through the opposite end of the furnace, until the welding rolls situated as close as possible to the furnace grip it and force it over the welding mandrel—the ball. When you remember that of the smaller sizes, a good welder will weld a pipe every thirty seconds, that he has to superintend the charging and the pushing out, in addition to regulating his furnace, that he is further responsible for the good production, that he must guard against burning his pipe, or shoving it out before it has reached the proper heat, in which case it would either stick in the rolls or weld imperfectly, you will realize that the job of welding is no sinecure. The designers of modern mills especially intended for the production of larger sizes have provided mechanical appliances for charging and pushing out, but the skill and responsibility of the welder is thereby not lessened.

The drawings, figure No. 12, show design of the welding rolls clearly. Pinions located in separate housings, pressure screws, bearings with side adjustment and counter balanced rolls and many other improvements in use in general rolling mill practice, are used here. The rolls run at a very high speed, the velocity of the welded pipe reaching as high as 800 feet per minute. The ball-shaped—somewhat like a cannon—shell is supported by a rod of much smaller diameter in exactly the center between the rolls. The pipe passes through these rolls, seam on top, the welding being effected by the pressure between the top roll and the ball, the ball in turn being supported by the lower roll. The welded pipe slips completely over the ball resting in the welding-trough. By means of friction rollers the bar is withdrawn from within the pipe, the ball dropping down in the front, and after inspection the pipe is either returned over the second run trough for a second welding, or sent forward in its course.

With the perfection of the Siemens furnace it became apparent that a greater number of the smaller sizes could be

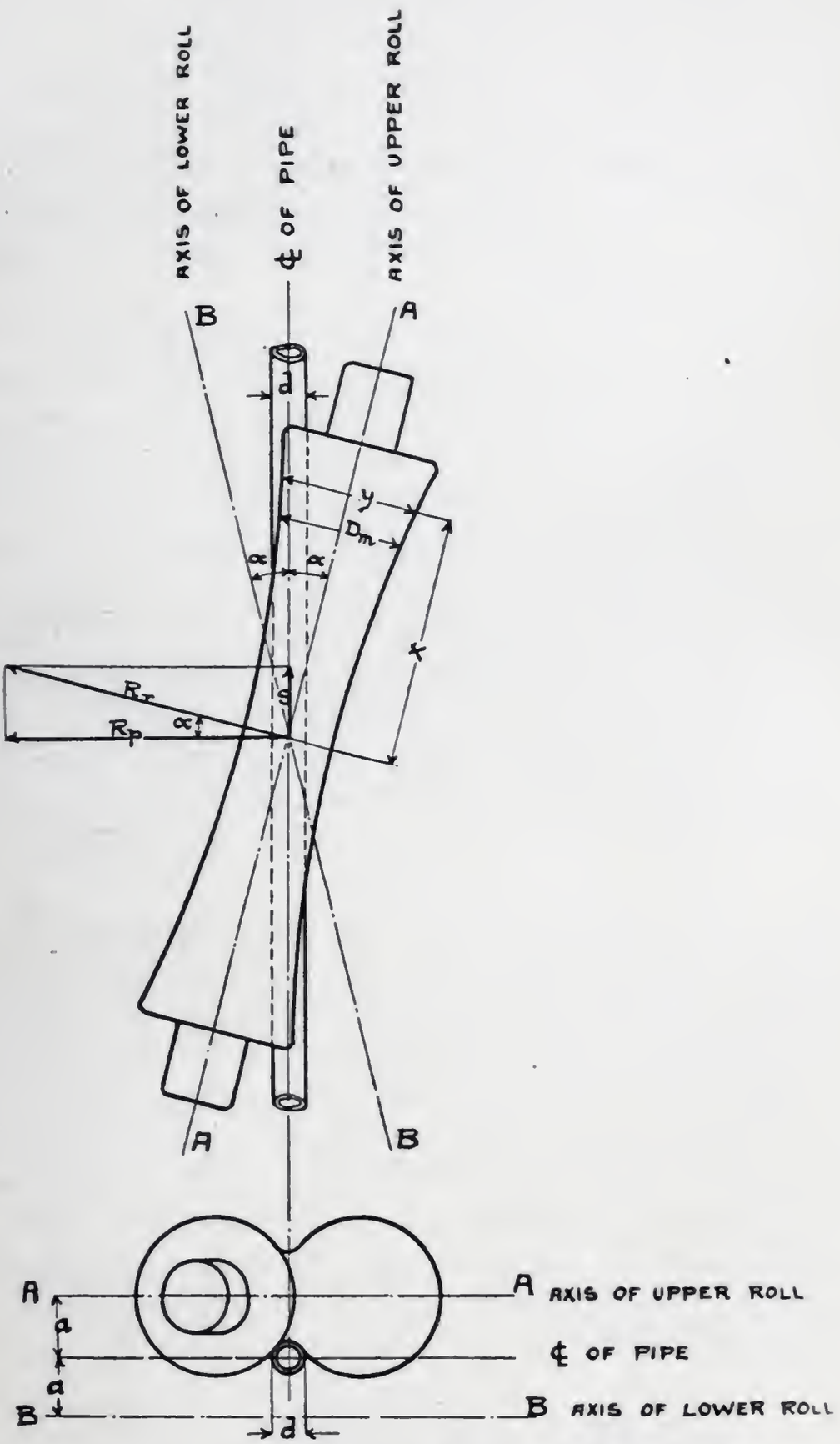


Fig. 13. Diagram of Cross Rolls for Straightening.

welded than one set of welding rolls and bar-puller could take care of, while with the larger sizes the operation of welding became slower and the machinery usually run ahead of the furnace. To increase the rolling capacity of small pipe, say below 6″, two gutters in the furnace were substituted for one, and double sets of welding rolls, or welding rolls with double grooves, were introduced, thereby increasing the output of a furnace considerably.

After the pipe is welded, it is passed through a set of sizing rolls built lighter but otherwise very much like welding rolls, where it is reduced to the exact outside diameter required. From thence it travels through the straightening machine, of which quite a number of designs are still in use. Smaller sizes are passed between large reciprocating plates, which roll the pipe back and forth until it is supposed to be straight, or the pipe is deposited between two long cylindrical rolls, set just far enough apart from each other to let the pipe drop through when perfectly straightened. The best method, however, for this purpose is to pass the pipe through two curved rolls arranged above or beside each other on inclined axis, which rotate the pipe, at the same time pushing it forward.

Figure No. 13 shows the theory of this appliance. To avoid complication only the axis B-B of the lower roll is shown. The surface of the roll wraps itself around the pipe, both furfaces being tangent along a line which is a helix on the surface of the pipe. The forward motion S is equal to the surface speed of the revolving roll Rr multiplied with the sine of the angle of intersection α while the surface speed of the revolving pipe Rp=Rr cos. α Owing to the varying diameter of the roll an average diameter must be taken in determining Rr. The curve of the roll proper is a rather complicated affair with the following equation:

$$y=\sqrt{x^2 tg^2 \alpha + a^2}\left[2-\frac{d}{\sqrt{x^2 \cdot in^2 \alpha + a^2}}\right]$$

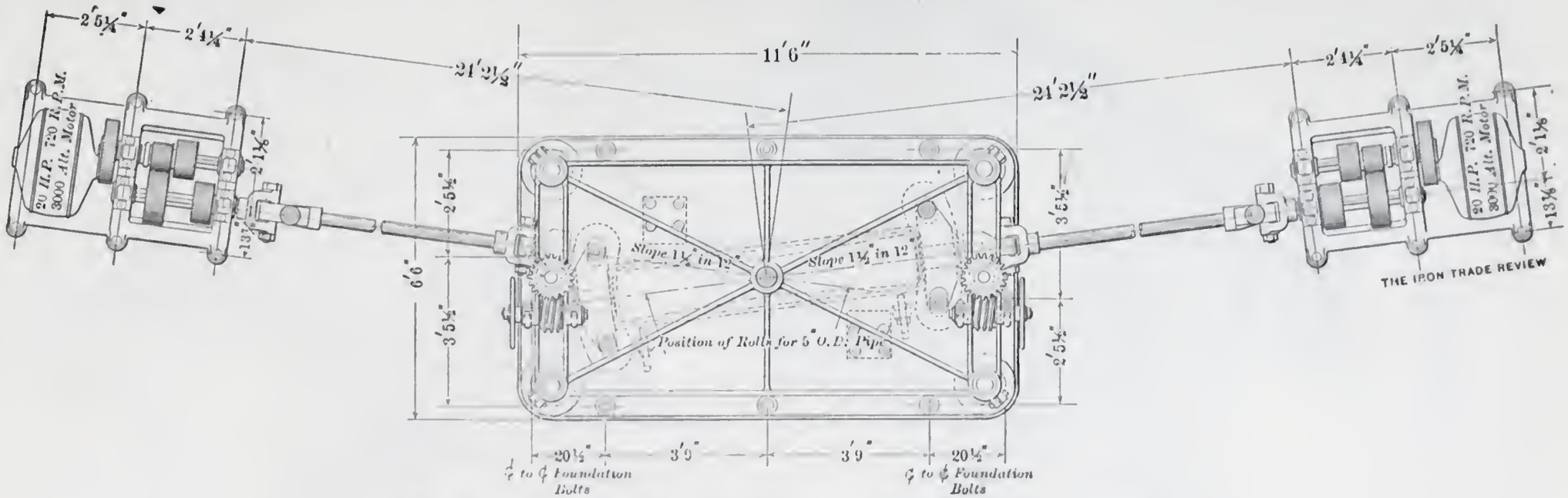


Fig. 14. Plan and Elevation of Cross Rolls, Horizontal Type.

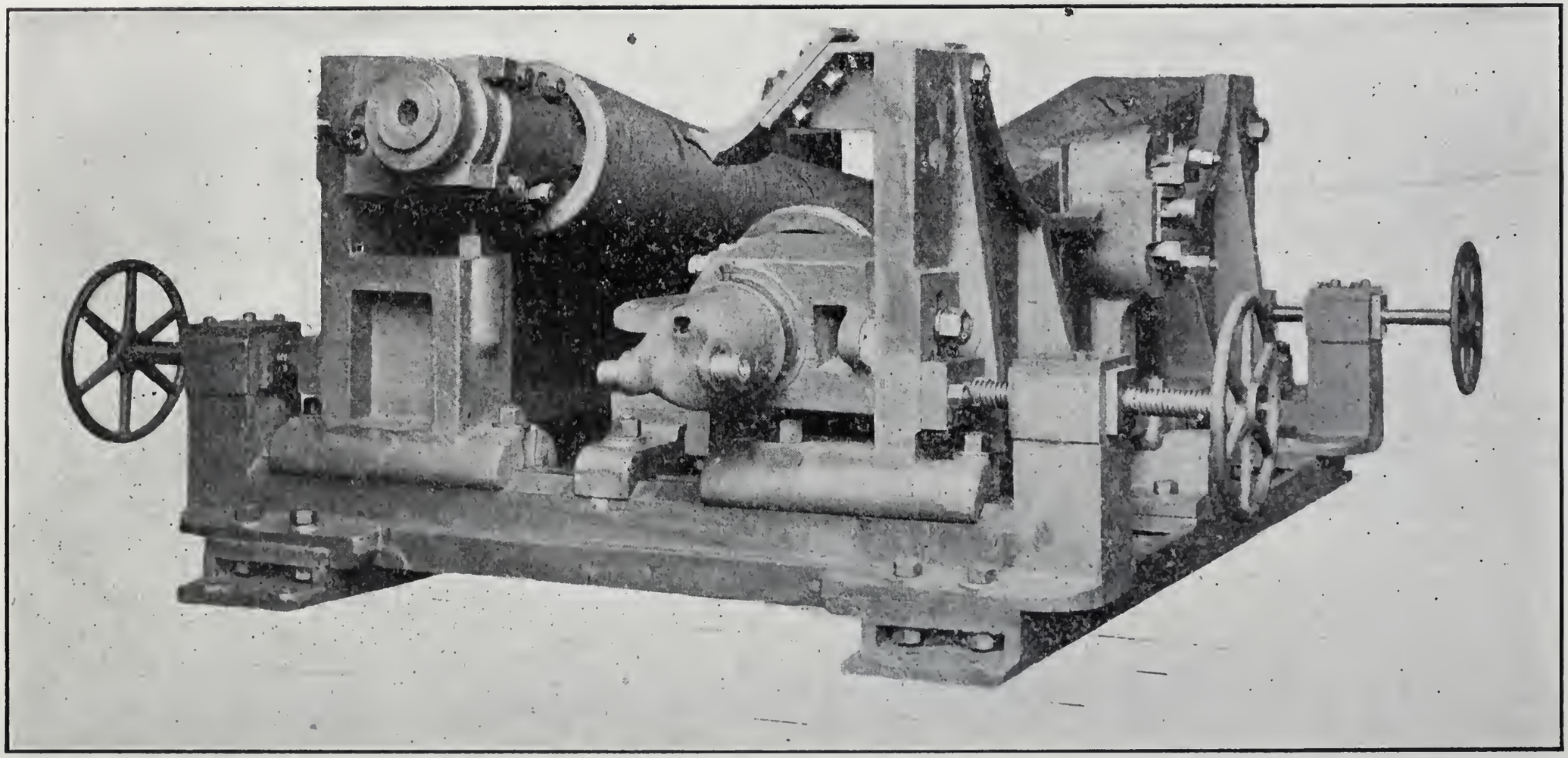


Fig. 15. Cross Rolls, Vertical Type, 24-inch Pipe.

It would lead us too far into detail to develop this equation, especially since it is without practical value. The proper way of turning the rolls is to fasten a bar of the proper diameter above it in the lathe intersecting it under the proper angle, and then to finish the roll until the proper contact has been accomplished. The drawings, figures No. 14 and 15, show various styles of these machines, in which the rolls are arranged either above and below or on the two sides of the passing pipe. The angle at which the axis of the rolls intersect the axis of the pipe is made adjustable, in order to use the machine for various sizes of pipe, it being apparent from the formula that for any given X and Y the angle of intersection α increases in a certain relation to the diameter of the pipe D.

From the cross rolls the pipe is brought upon a cooling bed, upon which it slowly travels sideways while it is held by a number of fingers of the traveling chains until it is cooled sufficiently to avoid the danger of having its shape again disturbed. The speed and angle of friction is usually figured, that as an additional precaution the pipe rolls around its own axis while traveling over the bed.

The machinery of a butt weld mill does not differ materially from the machinery described. Clipping shears are located conveniently at the charging end of the furnace, which clip the front corners of the skelp under an angle of 60°, leaving it about one-third of its original width. The skelp is charged over the whole width of the furnace hearth, strip beside strip, and as fast as the welder pulls out one piece a new one is charged in its place. The draw bench is of very similar construction to the one used for bending skelp, but the chain travels very much faster, reaching often a speed of 400 feet per minute. Rope has been substituted for chain with indifferent success. The bench travels sideways across the full width of the furnace, or is pivoted on its rear end, and swings through an arc sufficiently large to cover this width. The welder stands on a platform attached to the front or furnace end of the bench. He takes a bell, slips it over the tongs, grips the skelp in the furnace with these tongs, and hooks them to the traveling chain. The bell is pulled against a

steadying rest, and the tongs first and then skelp is drawn through its opening, the latter being bent and its edges forced against each other to a firm weld. Several boys assist the welder in unhooking the tongs at the proper time, cooling and cleaning the bells and supplying the welder with both as fast as he needs them. And he does need them pretty lively, since 2,500 to 3,000 pieces of 1″ butt weld pipe in 10 hours are considered a day's work.

The sizing and straightening machines and the cooling rack through which the pipe travels after being welded, are constructed on exactly the same lines as in the lap weld work, making allowance, of course, for the greater speed and lighter work.

A few words must be said here as to the manufacture of pipe couplings or sockets, as they are called in pipe mill work. Strips of skelp of the width of the socket and of a length to suit its circumference are heated, bent and welded into a ring. For smaller sizes, coal heated fires are used, while the larger sizes are heated in small regenerating furnaces. The bending and welding is done either in machines by a system of rollers, or by steam and trip hammers in dies. Hydraulic mandrels are forced into them to give the proper taper to their bore in both directions, to insure a tight joint when threaded and screwed onto the pipe. The tapping of these couplings takes place in multiple tapping machines of the same general type as seen in machine shops, only built stouter and heavier to stand the rough work.

After the pipe comes from the cooling rack it is inspected, and, if necessary, any kinks or bends taken out by a straightening press, built on the lines of the ordinary punching press, or operating by hydraulic power. The pipe is then distributed to the threading machines, which cut off the rough ends and cut the threads, if such is desired. There is a great number of threading machines in the market, all claiming certain advantages, but all built on the general well known lines of these machines. It must be said, however, that such machine, in order to do 20 hours of fast work every day under not very favorable conditions in a pipe mill, must be built far heavier

and far stouter than the ordinary jobbing machine used in machine shops. Rotary shears have been used lately with great success to cut the crop ends and have thus greatly relieved the work of the threading floor. Before leaving the mill every piece of pipe is subjected to a test by hydrostatic pressure, varying according to the size and purpose of the pipe from 300 to 3,000 pounds per square inch. On a bed, built similar to a lathe bed, one stationary and one moving head are mounted. The pipe is inserted between the two, the moving head brought forward until a tight joint is effected. The pipe is then filled with water from an ordinary supply line and by means of a three-way valve pressure of the desired intensity is applied. Only pipe passing the specified test are allowed to leave a modern mill.

I will conclude my talk with a short explanation of the various ways in which the rolling machinery of a pipe mill is usually arranged. Lap weld mills running on ordinary standard pipe—and this is the product of the greater number of our mills—will use the arrangement shown on figures 16 and 17, using only one welding furnace. A good superintendent will be able to turn out a product coming up to the specifications of standard pipe by finishing at least 80% of the output in one welding or in one run, as it is called; the balance which might not have been safely welded, can be readily returned to the furnace by suitable appliances for the second run. Quite different, however, are the conditions in a mill running on a product like boiler flues, where the customer insists upon a double run as part of his specifications. Then a double welding furnace mill, as shown on figure 18, will be preferable, the pipe passing through the operation as shown by the arrow heads. The different arrangements as shown on figure 16 and 17 are usually determined by the available floor space, the arrangement in figure 16 taking up about 90 feet in width by 160 feet in length, while the arrangement as shown in figure 17 takes 60 feet in width by 270 feet in length. The first is preferable, when it can be installed, since it avoids the turning end for end of the bent skelp between the bending bench and the charging machine, necessitated by the fact that the part

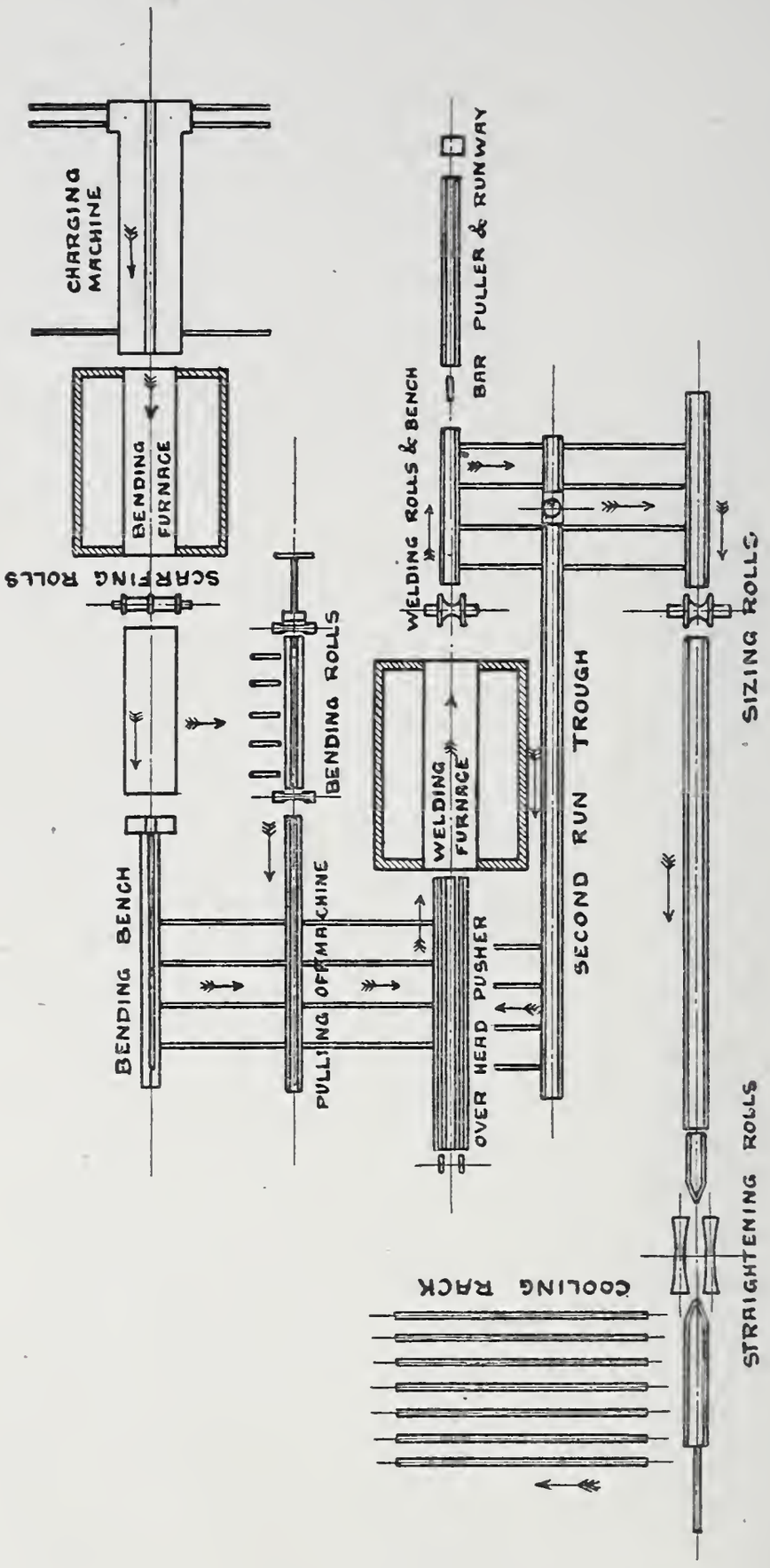


Fig. 16. Lap Weld Mill for 8 to 24-inch Pipe.

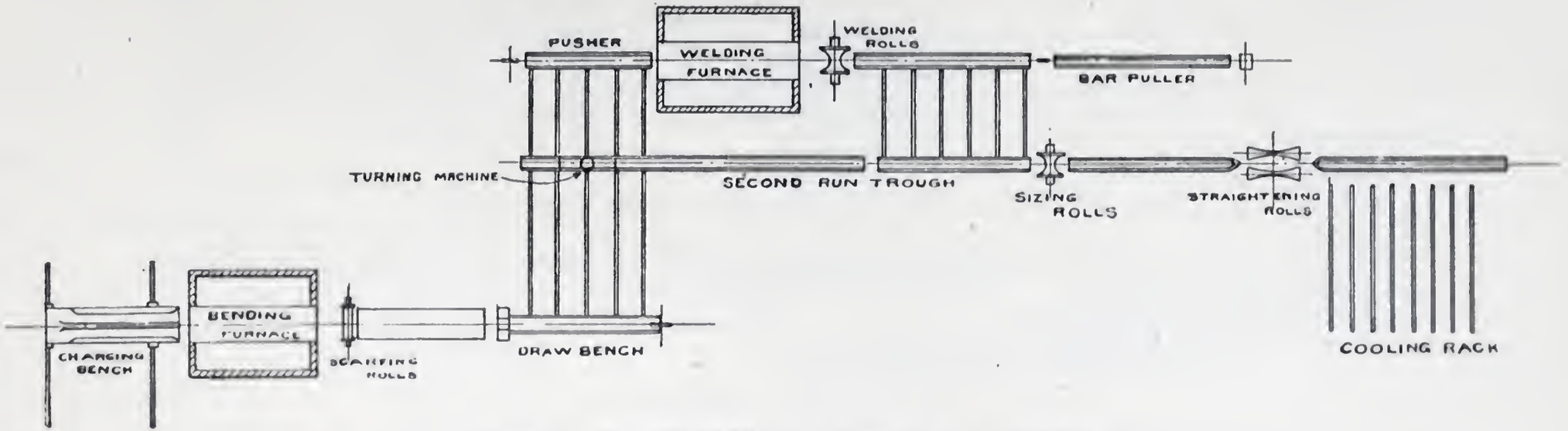


Fig. 17. Lap Weld Mill for Pipe up to 8 Inches.

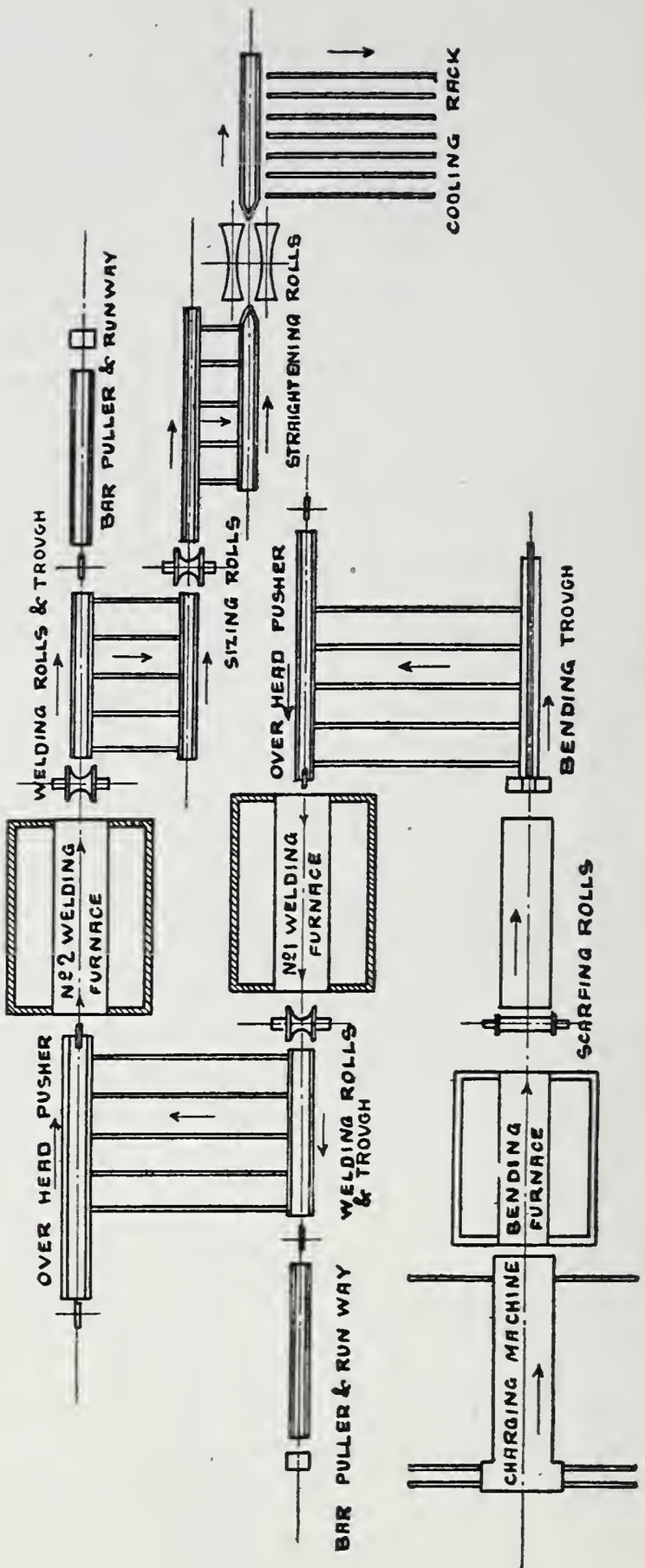


Fig. 18. Double Welding Furnace Mill.

of the skelp which leaves the bending die last must enter the welding rolls first, the other end being badly used up and battered by the skelping tongs. Figure 16 shows a mill for large pipe and, therefore, a set of bending rolls for pipe skelp above

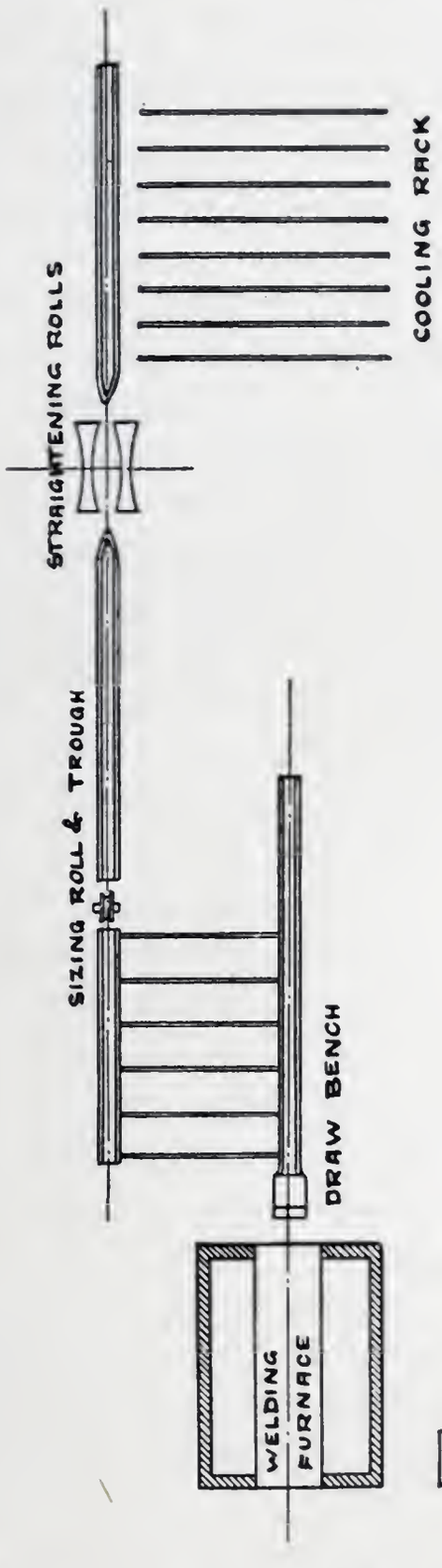


Fig. 19. But Weld Mill.

12″ is added. Figure 19 shows a butt weld mill, the arrangement of which can be readily understood.

DISCUSSION.

MR. CAMP—Gentlemen, Mr. Beutner has told us everything but how to "hit the pipe." The paper presented was quite an interesting one, and I do not doubt it will be very learnedly discussed.

MR. DIESCHER—I have not much to say, but rise to mention that in making butt-welded pipe of so small size that tongs cannot be put through the hole in the bell; it is common practice to weld a thin rod to the end of the skelp and put the rod through the bell, then grip it with the tongs.

MR. BEUTNER—That is quite true. The method given by Mr Diescher is called "tagging," and is in use in mills where some orders for the small sizes have to be executed in bell weld mills. As a matter of fact, I think that these mills try to keep as far as possible away from making this small pipe. It will be cheaper for them to refuse such orders, but in case some small pipe is included in a very large order it would be advisable for them to buy it from mills which make a specialty in rolling the smaller sizes by the tongue process.

MR. ELY—I would like to have Mr. Beutner tell us if seamless pipe goes through the same operations.

MR. BEUTNER—I was afraid of being drawn into a discussion of seamless pipe to-night. The mills which do manufacture this product are probably more closely guarded than the mills manufacturing welded pipe. However, on the whole, the drawing is done in the same way as in other branches of the iron and steel business. I have never had any actual connection either with the designing or operating of mills manufacturing seamless pipe.

MR. CAMP—I noticed in the analysis of the material which Mr. Beutner gave the carbon was pretty low, 5 per cent., I think, for soft steel. We make a little bit of that ourselves once in a while. Our limit is 8 per cent. to 10 per cent. carbon.

MR. BEUTNER—I shouldn't wonder that those conditions have changed a great deal. The analysis I give was taken from a paper belonging to Mr. Brahm, who was probably more careful than the manufacturers of to-day.

MR. CAMP—Would it not be better to put it the other way, and say that he was just learning?

MR. DIESCHER—The manufacture of seamless pipe starts out with a round billet, through which, after proper heating, a hole is pierced, after which the billet is rolled in an ordinary mill until the desired diameter and thickness of metal is attained. There are various machines employed for piercing, as the drawings of Mr. Beutner show, but they all have this in common, that they roll the billet transversely to the direction of its geometrical axis. By rolling a billet in this manner, it occurs that the material forming its core is gradually drawn toward the circumference, as it were, in a radial direction, in consequence of which the billet becomes hollow. Of this peculiar feature advantage is taken in piercing by driving a mandrel with a pointed head, made of steel, into the opening produced during rolling, in a manner that the mandrel moves forward at the same speed at which the point of contact and pressure between rolls and billet advances. The force required in driving the mandrel into the billet is very moderate, compared with that required in the ordinary punching process. The introduction of the mandral serves the double purpose of making the diameter of the hole to suit subsequent operation and to make the inside surface uniform and smooth. After piercing, the billet is reheated, if not still hot enough, and put through an ordinary mill having round passes turned in its rolls. In this operation also a mandrel is employed, in such a manner that it is always situated where the rolls press the billet. Thus the metal around the mandrel is reduced and so transposed as to increase the length of the piece without reducing its inside diameter.

Recently another type of mill was constructed and is now employed in Germany, instead of the usual rolling mill, for rolling pierced billets. This type is designated a "swedging mill." It consists chiefly of two triangular segments of disks, a housing and a combination of connecting rods and cranks by which the segments are made to oscillate. The arcs of the segments face each other. The apexes and fulcrums of the triangles are located opposite each other. The arcs are not concentric with the fulcrums, but their centers are located somewhat aside of those of the fulcrums. Thus when the segments perform their oscillating motions the space between the two opposite arcs—which are never in touch—is alternately growing and decreasing.

By reason of this difference in the opening between the jaws of the segments, it is possible to insert a bar of hot metal when the opening is wide enough to receive it, and, as the segments proceed to close, the bar will be squeezed and thus reduced in thickness, and if the bar is turned after every bite, it will be reduced all around and brought to a diameter equal to the minimum opening of the jaw. In this way a bar of considerable length can be rolled down by turning and feeding it into the mill at the rate as the segments can do their work. The usual speed at which the vibrations of the segments occur is about 240 per minute. In employing this mill in the manufacture of seamless tubing, a mandrel is inserted into the billet and so held in position that it is always at the place where the work of reduction goes on.

In Germany there is at present, also, a straight punching process employed for the production of hollow billets, but the tool used in piercing is not of the shape of an ordinary punch, but is pointed, owing to which it does not push out the core of the billet, but only displaces it by forcing it toward the periphery.

MR. CAMP—Is this a cold-drawn process?

MR. DIESCHER—No; by this process the pipe is put through hot. The length of which a tube can be made by the use of the swedging mill depends on how long the billet retains the heat necessary for rolling. In this mill the whole reduction is accomplished in one single pass, and for this reason the heat is not retained so long as in the usual way of rolling, in which a billet goes through a number of passes whereby the temperature of the piece rolled is maintained more constant until the section is very much reduced when cooling occurs faster.

The cold drawing process is employed in producing tubes of very exact dimensions. It follows the rolling process and is carried out by alternate annealing and drawing until the desired thickness of metal and diameter is attained. In this manner tubes may be produced of almost any shape of cross section, round, half round, oval, square, etc., and the thickness of the metal may be brought to an exactness of 2/1000 parts of an inch. Such tubing is used in constructing bicycle frames and the like.

MR. FLANAGAN—Some years ago I assisted in the design, or rather the partial design, of a machine for cleaning the cores out

of ingots which were cast hollow for use in the manufacture of seamless tubes. The ingots were designed to be six feet long, and to have a four-inch core in them, and we were expected to build a machine to force the core out, and, at the same time, leave the interior of the ingot so clean that it would be suitable for extending into a seamless tube. I might remark that we never finished the machine. The parties who had the idea gave it up finally, and I believe that the reason it fell down was the characacter of the cutter that would have to be forced through the ingot. The machine was simply a powerful hydraulic press, intended to force a bar with a cutter head hot through the hole, cleaning the rough sand and scale from it. I think the difficulty was in providing a cutter head that would stand up to the work; that was the reason the machine fell through. Briefly speaking, it involved a broaching operation on an unusually extensive scale. Whether such a machine has ever been used I don't know. I bring it up to-night in the hope that Mr. Beutner or Mr. Diescher may discuss the possibilities of such a plan.

MR. KINTNER—Mr. Chairman, I would like to just ask, What constitutes a good output from an average-sized mill, welding say 5 or 6-inch pipe?

MR. BEUTNER—This question cannot be answered to a certainty. I know a pipe mill equipped with double-grooved rolls, which I described above, which makes 1,200 pieces of 4-inch pipe in 10 hours. I know of another mill which turns out 800 to 900 pieces of 4-inch tubing, each one double welded, in 10 hours. As the sizes of a lap weld mill increases, the number of pieces turned out decreases very materially. Two hundred pieces of 12-inch pipe in 10 hours is a good output. I gave above 3,000 pieces of inch pipe in 10 hours as a good product of a butt-weld mill.

MR. FLANAGAN—The pipe on the market is usually sold in random lengths, and I would like to ask the gentlemen what is the length which the mills are laid out to roll, and also what is the maximum length the purchasers are likely to get hold of.

MR. BEUTNER—The longest lengths for which mills are usually laid out is 22 feet. The length depends so much upon the nature of the pipe and the nature of the work for which the pipe is wanted. It is pretty hard to answer the question intelligently.

MEMBER—There is a little question in pipe manufacturing that it seems has been dodged a great deal—the thing has been bothering me. The question of that mandrel. They just get up into that mandrel and then they stick. It seems to me that there would be quite a question in regard to pipe manufacturing. Are they going to leave it in there as a little short piece or tie something to it? They have got to have some way to get it out of there. I would like to know something about what that mandrel is, how it is operated and what it is tied to.

(Mr. Beutner explains the mandrel, etc., to the gentleman, illustrating his remarks on the blackboard.

MEMBER—I would like to ask about how much is allowed in the length of the skelp in figuring the length of the finished pipe.

MR. BEUTNER—Not very much. You can figure that the length of the original skelp is about the length of the finished pipe. The tendency is not to stretch it. If you take a 20-foot skelp you usually get a 20-foot pipe out of it, allowing for several inches on each end for the ragged edge.

MEMBER—One more question. What do you mean by the upsetting of pipe? The upsetting of the ends?

MR. BEUTNER—There are 150 different joints in the market. Some of them are prettily illustrated in the hand-book of the National Tube Works. There is not any difficulty in doing this.

MEMBER—Has it a tendency to put a greater amount of material on the end?

MR. BEUTNER—The idea is to strengthen, either for holding the flange or for facilitating the expanding of the end in boiler work.

MEMBER—Isn't it to give equal strength for tensional stress at ends of pipe?

MR. BEUTNER—What do you want tension on a pipe for?

MR. DIESCHER—The purpose of upsetting the end of pipe is to compensate the loss of strength caused by cutting the threads. The upsetting is of such thickness that after the thread is cut the metal at the root of the thread is of same thickness as in the rest of the pipe. The object in this instance is the same as in upsetting ends of tension rods in structural work. The upsetting

of pipe ends was suggested by the trouble encountered with long lines of pipe, particularly as used for natural gas mains, where, owing to the high pressure and expansion and contraction the pipe suffered mostly in the threaded portions.

MEMBER—Since the subject of the expansion of pipe has come up, has there been anything done yet in the case of underground pipes that may be subjected to expansive tests? Say, for instance, a pipe several hundred feet long that has to carry alternately hot and cold water—has anything developed yet in taking up the expansive strain in a case of that kind? Can you say anything about that, Mr. Diescher?

MR. DIESCHER—Not long ago I saw a joint in the main steam line at the City water works, at Brilliant Station. That joint is very good and consists chiefly in this, that at some convenient point the steam pipe is cut off and closed; some distance from the end of this pipe a sleeve of considerably larger diameter than that of the pipe is put over this latter and provided at each end with a stuffing box and gland. The pipe within the sleeve and for some distance beyond the glands in either direction is finished to make a tight fit with the glands and packing. The sleeve is provided, on two opposite sides, with flanged stubs that are connected by a "U" shaped pipe lying in the same plane as the steam pipe. From the bend of the U pipe a flanged stub projects from which the steam pipe is continued. That portion of the pipe within the sleeve has several slots through which the steam enters the annular space within the sleeve, whence it passes by way of the U pipe into the second section of the steam main and on. With this joint the range of expansion and contraction can be made to answer any demand.

MR. WHITED—I would like to have some of the gentlemen present answer a little question. Some years ago in New York City a great steam generating plant was placed in the downtown section of the city, with pipes running to different parts of the city to supply heat and power. They had trouble on account of the expansion and contracting. They have gotten around that. Now, can anybody tell us how they did it?

MEMBER—I would like to ask how large that pipe was?

MR. WHITED—I don't know exactly—they were very large, though. They were torn up there after that time in New York for a long time on account of it, but they do not have any trouble now.

MR. MULLEN—Why are ground spots found on the outside of a large welded pipe? What produces them?

MR. BEUTNER—This question is a sticker. These spots can be seen very often in the weld of the pipe. They are not caused by the machinery, but are conditioned by the nature of the material. They do look somewhat like smallpox. I do not know what causes them, but they can be seen very often.

MEMBER—One question I would like to ask in this regard, is how are large pipes bent?

MR. BEUTNER—There is a limit of the radius to which a pipe can be bent, which varies with the size of the pipe. The smallest radius to which a pipe fitting concern will undertake to bend a pipe is usually given in their catalogues. The pipe is filled with sand, heated, and then bent by hand, but it is very seldom done in pipe mills.

MR. CAMP—Any more discussion, gentlemen?

MR. KINTNER—I move that the Society extend a vote of thanks to Mr. Beutner for his paper. (Motion seconded and carried.)

Motion to adjourn seconded and carried.

CHARLES W. RIDINGER, *Secretary.*

CHEMICAL SECTION

The regular monthly meeting of the Chemical Section was held Thursday evening, December 17, 1903, in conjunction with the Pittsburg Section of the American Chemical Society, Mr. H. N. Craver, Chairman, presiding. In absence of the Secretary, Mr. George P. Maury was appointed Secretary pro tem. The minutes of the last regular meeting were read, corrected and approved. The paper of the evening followed: "The Analysis of Red and Black Paint," by Mr. Charles G. Snyder.

ANALYSIS OF RED AND BLACK PAINTS.

BY CHAS. G. SNYDER.

As it would be impossible to try to consider methods of analysis of all paints in the brief time that can be given to a paper of this kind, I have confined this paper to the analysis of red and black paints. All paint analyses are similar in some portions, the differences arising from the differences in the composition of the solid materials composing the various paints. Paints are used either to protect materials from the destructive effects of the weather or for decoration.

Most building materials are more or less acted upon by atmospheric changes, and also by noxious gases. Metals are oxidized and corroded, while wood decays. By covering these materials with a coating of paint the weathering action is moderated, and consequently the materials retain their strength for a much longer time.

Paint is a mixture composed of a finely pulverized body called pigment and a liquid material termed the vehicle or binder. There are two varieties of paint, oil and aqueous. The aqueous paints resemble whitewash and as an analysis of such paints is very seldom made, I will not devote any time to them. The pigment of a paint consists of one or more substances which are acted upon very slowly by atmospheric influences, and which possess sufficient opacity to hide the surface to which they are applied as paint. Oil and turpentine alone will form a protective film, but the resulting coating is transparent. The vehicle is the liquid in which the pigment is ground or mixed, and which serves to spread the pigment over the surface to be painted and which holds the pigment to that surface. The vehicle may be oil or varnish. This oil must necessarily be a drying oil. The vehicle used most commonly is linseed oil. A mixture of pigment and linseed oil can not be spread readily with a brush, so it is necessary to add some liquids called thinners. Of these there are two which are almost universally used, turpentine or naphtha, and a few others which are occasionally used. Oil paints, when

ready for application, are, therefore, composed of pigment, oils and turpentine. The turpentine in many paints is almost entirely displaced by naphtha.

The property which gives linseed oil its value as a paint oil, is that on exposure to air in a thin coating it absorbs oxygen and becomes a firm, hard mass, which resists to some extent atmospheric changes. This property of drying has been found to be increased by heating raw linseed oil to about 500 degrees Fahrenheit, more especially if during the process of heating a body known as a drier is added, the presence of which promotes the obsorption of oxygen.

As it requires about three days for raw linseed oil to dry, many paints contain this heated oil, or, as it is called in the paint world, boiled oil. The driers added to linseed oil are compounds of manganese or lead, usually. Dryers can only be substances such as are capable of forming 2 or 3 compounds with oxygen. When paint dries the drier absorbs oxygen from the air, forming an oxide containing more oxygen than the original oxide, which was incorporated in the paint. This higher oxide gives up this acquired oxygen to the oil, becoming again the original oxide. This change is repeated many times, until the paint becomes hard and dry. Linseed oil is thus oxidized into a compound called linoxyn. The life of any paint depends to a very large extent upon the life of the oil or binder as the oil is often called.

The principal substance in the pigment of a red paint is iron oxide, and in black paint is some form of carbon. Very seldom does the pigment of a red paint consist only of iron oxide; neither does a black paint have carbon for its only solid material. Usually paints contain what is known as inert material, such as whiting ,gypsum, barytes, kaolin, slica, talc and feldspar. This inert material is added as a filler and also to cheapen the cost. Marble dust is used extensively as a source of calcium carbonate instead of whiting.

I will first consider black paints. The color of black paints is furnished by some form of carbon, as lamp black, drop black, bone black, graphite, etc. Carbon black, made from natural gas, is a very fine black pigment.

Coal tar pitch is much used as a paint for the roughest class of

work, such as coating iron pipes, smoke stacks, etc. Coal tar pitch has the disadvantage of becoming exceedingly brittle by the action of cold, and softening at about 120 degrees Fahrenheit. A coal tar paint is easily distinguished by its odor. Sometimes coal tar pitch is mixed with a coal tar oil or carbon disulphide, and then becomes a liquid paint. Asphalt is occasionally used as the basis of a black paint. The use of asphalt permits of a somewhat wider range of temperature than coal tar pitch, but otherwise is quite similar. As liquid paints made of coal tar pitch or asphalt are seldom misrepresented and are quite cheap, analyses of them are never required. To analyze a black paint containing the substances usually found in them, the method of procedure is as follows: From 5 to 10 grams of paint are weighed into a dry erlenmeyer flask. From 25 to 50 C. C. of petroleum spirit (none of which distils above 85° C.) is added to the flask, which is then agitated. The flask is then allowed to rest until the pigment has settled, leaving a clear, supernatant liquid, which is then poured off and preserved in another weighed flask. The treatment with petroleum spirit is repeated till the petroleum spirit ceases to be colored by the oil of the paint. About 4 or 5 treatments are usually sufficient to remove all of the oil. The object of this treatment is to get the pigment separated completely from the oil. The flask containing the pigment is then dried to a constant weight at 100° C. The petroleum spirit containing the oil of the paint is preserved and will be treated of later.

About one-half gram of the dried pigment is boiled with dilute hydrochloric acid, filtered on a weighed Gooche crucible with an asbestos filter. The residue on the filter is washed and then dried and weighed. The weight found is the weight of the insoluble silicates, silica and carbon. The residue is then ignited and weighed again. The loss is the carbon. Weigh out another portion of about one gram. Boil with dilute hydrochloric acid, dilute, filter and ignite the residue, which is then fused with sodium carbonate. Transfer the result of the fusion to the same dish that contains the filtrate from the treatment with hydrochloric acid. Evaporate to dryness twice to render silica insoluble; take up in dilute hydrochloric acid and filter. The residue is then ignited and weighed as silica. Pass

sulphuretted hydrogen through the filtrate from the silica to precipitate sulphide of lead. Filter off the lead sulphide and dissolve the precipitate in dilute nitric acid, then add sulphuric acid, and precipitate lead as lead sulphate. Oxidize the filtrate from the lead sulphide with nitric acid and precipitate the iron and aluminum by the basic acteate method.

Dissolve the precipitate in hydrochloric acid, and precipitate the iron with sodium hydrate; filter off the precipitate of ferric hydrate, ignite and weigh as sesqui oxide of iron. Precipitate the alumina as hydrate in the filtrate from the precipitate of ferric hydrate. Add bromine to the cooled filtrate from the combined precipitate of iron and aluminum acetate, and then ammonia. Boil for a few minutes, then filter off the precipitated manganese dioxide. Wash, dry, ignite and weigh as manganese tetioxide and calculate the manganese present as existing in the form manganese dioxide. Heat the filtrate from the precipitate of manganese dioxide to boiling and add ammonium oxalate and ammonia. Filter off the calcium oxalate; ignite and weight as calcium oxide or titiate the precipitated calcium oxalate with a standard solution of potassium permanganate. Test the filtrate from the calcium oxalate precipitate for magnesia which if present is precipitated in the usual manner and calculated as magnesia. When compounds of lime are present in considerable percentage, magnesium is almost always found.

To detect the presence of calcium sulphate in the pigment, some of it is boiled with water. Sufficient calcium sulphate is dissolved to prove its presence. This solution is tested for compounds of calcium with ammonium oxalate, and for sulphate with barium chloride. If both tests give positive results the calcium found in the pigment may all exist as calcium sulphate. A definite way of deciding whether all the calcium exists as calcium sulphate is to boil about one-half gram of the pigment with hydrochloric acid. This dissolves all the calcium sulphate, and, in fact, every sulphate except barium sulphate. Filter off the insoluble matter and precipitate the sulphates with barium chloride. Calculate all the calcium found as calcium sulphate, and if there is an excess of sulphate some other element must exist in the paint as a sulphate. A determination of carbon dioxide

is often useful, as it proves whether there are any free carbonates existing in the pigment. To determine carbon dioxide, treat about 5 grams of the dried pigment with dilute hydro-chloric acid in a suitable absorption apparatus. The carbon dioxide is then weighed.

The petroleum spirit which contains the oil of the paint is heated to 100° C. to constant weight to thoroughly remove the spirit. The residual oil is then weighed. This oil will contain the linseed oil of the paint: It may also contain mineral oil, rosin oil, cotton seed oil, fish oil and other adulterations or substitutions. To examine the oil of a paint, 50 grams or more of the paint must be taken, and the oil removed by petroleum spirit, or ether. The petroleum or ether is evaporated off at 100° C. C.; the oil is then ready for further examination. To determine the purity of the linseed oil it must be subjected to several tests. The specific gravity of genuine linseed oil varies from .932 to .937. Linseed oil is certainly adulterated if the specific gravity varies very much from these figures.

The percentage of mineral oil is found by saponifying about 5 grams of the oil with about 30 C. C. of a solution of alcoholic potassium hydrate. This alcoholic caustic potash solution is made by dissolving 80 grams of caustic potash in 1 liter of wood alcohol. The alcohol is then boiled off, water is added to dissolve the soap. The solution is then transferred to a separatory funnel and shaken with about 50 C. C. of ether. The treatment with ether is repeated two or three times. The aqueous portion which contains all the saponifiable matter is tapped off and the ethereal portion containing the unsaponifiable matter, such as mineral oil, is transferred to a weighed dish and the ether is driven off, either by a stream of air or by heat not exceeding 100° C. The mineral oil in the paint is found in the dish after the ether is evaporated. The dish is weighed and the gain in weight divided by the original weight of oil gives the per cent. of mineral oil.

Rosin oil is detected in linseed oil by the increased specific gravity, by the altered flash point of the oil, by the odor of rosin evolved on heating, and by the Lieberman-Storch reaction. This is as follows: One to two C. C. of the sample is shaken with acetic anhydride at a gentle heat. Cool, draw off the acetic anhydride

by means of a pipette, and test it by adding one drop of sulphuric acid. If rosin oil be present a fine violet color is immediately produced.

Another test for rosin oil is a follows: Saponify the suspected sample with alcoholic potassium hydrate, evaporate off the alcohol, dilute with water, boil about one-half hour. The unsaponified portion will float on top as an oily layer. Draw off the aqueous layer, filter and acidify; filtrate with hydrochloric acid. The rosin acid will separate out in drops of characteristic smell. The best method to determine the quantity of rosin oil is that devised by Twitchell. As the method is somewhat lengthy, I will refer to Pages 107 and 108 of Allen's Commercial Organic Analysis, Vol. II, Part 1, for a complete description of this method.

A 4th test to be applied to the oil extracted from the paint is the test for rosin spirit. The specific gravity of rosin spirit varies from .876 to .883, while that of turpentine is about .865. The flash point of it is about the same as turpentine. A sample of rosin spirit should all distil below 250° C. If rosin spirit is contained in the paint it would distil with the turpentine, when the paint is subjected to steam distillation. The distiliate is then tested for specific gravity and is distilled. The rosin spirit is distinguished from turpentine by the continual increase of temperature during the process of distillation. Turpentine all distils over between 150° and 170° C. Only a portion of the rosin spirit distils between these points. The residue in the still after the turpentine has been distilled off, is tested for rosin spirit by burning the oil. The odor of rosin is given off if rosin spirit is present.

A 5th test to be applied to the oil from paint is the test for rosin. This is best detected by applying the Lieberman-Storch reaction. In this case an alcoholic extract of the oil should be used to detect rosin. It is also detected and determined by determining the acid value of the sample using phenolphtalein as an indicator and multiplying the number of C. C. of normal acid used by .346 which gives the weight of rosin. The free fatty acids in linseed oil are usually very small, otherwise the above method of titration could not be used. The percentage of rosin is determined by applying the Twitchell method.

A 6th test to be applied to the paint oil is the test for cotton

seed oil. Halphen's test is the very best one if the oil is not too deeply colored. This test is carried out as follows: Carbon disulphide, containing about one per cent. sulphur in solution, is mixed with an equal volume of pentyl alcohol. Equal volumes of this reagent and the sample about 3 C. C. of each are mixed and heated in a bath of boiling brine for 15 minutes. If no red or orange tint is produced, 1 C. C. of the reagent is added and if after 5 or 10 minutes more heating no color is shown, a 3d addition of 1 C. C. may be made.

A 7th test to be applied to paint oils is the test for fish oils. There are various color tests, but none of these are of consequence. The only reliable test for these oils is the smell of the sample on warning. To distinguish between raw and boiled linseed oil: the specific gravity may distinguish them. The difference in raw linseed oil has a specific gravity of from .932 to .937, while boiled oil has a specific gravity of from .940 to .950. The percentage of iodine absorbed by raw linseed oil is about 180, while boiled oil may absorb anywhere from 75 to 150. One of the best methods is to apply a drying test. Boiled oil will dry in 24 hours, while raw linseed oil will only have a thin skin over it in that time.

The presence of dryers, such as manganese or lead, in the oil proves that it is boiled oil. The dryers are detected by boiling about 25 to 50 grams of the oil with dilute hydrochloric acid and allowing the solution to separate in two layers. The lower or acid layer is tested for manganese, lead, etc.

I have given above the tests to be applied for the identification of rosin oil, rosin spirit rosin, cotton seed oil, mineral oil and fish oils, in linseed oil. There are a number of other tests which can be applied to any oil which can be and often are applied to linseed oil to determine its purity such as the percentage of iodine absorbed, the elaidin reaction, by which various products are produced by shaking the oil with a solution of mercurous nitrate, saponification, equivalent, temperature, reaction, and color reactions, with various reagents. All these tests are of more or less value. Pure linseed oil gives greatly varying results with these tests and one should never judge of the purity of linseed oil after applying only one test. In fact it is sometimes difficult to give a

positive opinion after applying all of these tests. One of the very best methods of detecting adulteration in linseed oil is a drying test. Pure linseed oil without driers ought to dry quite hard in three days when spread in a thin layer on glass. When five per cent. of liquid drier has been added, 24 hours is sufficient to dry linseed oil. Boiled linseed oil also requires about 24 hours. Rosin, mineral, and cotton seed oil materially increase the length of time to dry. To determine the percentage of turpentine in a paint, 50 grams or more of the paint are weighed into a distilling flask, which is connected with a source of steam and a condenser. Steam is passed through the paint, carrying with it the turpentine and light mineral oils, also the rosin spirit. The mixed water and oily distillate is collected in a separatory funnel. The steam is passed through the paint as long as any oily distillate comes from the condenser. The water is tapped off and the oily distillate is transferred to a dry flask and weighed. The specific gravity is taken and if it is between .864 and .870 it is probably pure turpentine. The flash point is also taken. If this is below 95° F., it is a certain indication of a mixture of turpentine and some other liquid or an entire absence of turpentine. If the paint contains naphtha in addition to turpentine, the gravity and flash point of the oily distillate show conclusively the presence of naphtha. In some paints no turpentine exists at all and the distillate from the steam distillation shows this most clearly. To determine how much of the distillate from the steam distillation is naphtha, the oily distillate is treated with fuming nitric acid, in a large flask of about a liter capacity connected with a return condenser. The oily distillate is run into about 3 times its volume of fuming nitric acid very slowly, as the action of the acid on turpentine is very vigorous. The turpentine is oxidized completely, and the mineral oil is only slightly affected. The products resulting from the treatment are transferred to a separatory funnel and the oxidized turpentine is thoroughly removed from the naphtha by washing with hot water. The naphtha is then measured to determine its quantity. The mineral oil can then be further examined by taking its specific gravity and flash point. Some useful information can be gathered by distilling it as to its nature. The naphtha ordinarily

used by paint makers has a specific gravity of .74 and it distils completely below 150 degrees C.

In the paint market there are to be found liquids known as driers or japans. These liquids consist of mixtures of boiled oil, turpentine and naphtha with the compounds of lead, such as red lead or litharge and manganese dioxide. In addition, the liquids may contain one or all of the following: Rosin, gums of various kinds, lime, compounds of zinc and iron. To analyze one of these liquid dryers burn from 50 to 100 grams in a large porcelain crucible. The residue consists of the solid matter which was dissolved in the oil, such as the compounds of lead and manganese. This is analyzed according to the scheme given for black paint pigments. The turpentine, naptha and rosin spirit are determined by passing steam through from 50 to 100 grams. The distillate is collected and separated by the method already given. Methods of determining the percentage of gum in a liquid dryer are mere approximations only. To determine the oil in dryers consult page 155 of Allen's Commercial Organic Analysis, Vol. II, Part 1.

We will next consider red paints. By far, the pigment used most commonly in red paints is the red oxide of iron. This oxide is found in some natural deposits in sufficient purity to be used as a pigment. The purest iron oxide is obtained by precipitation of ferric hydrate and reduction to the oxide by calcination. The precipitated oxide is sold at a considerably higher price than the natural oxide. To analyze a red paint the pigment is separated from the oil by means of petroleum spirit or ether. As the percentage of iron oxide is usually quite high, the iron can be determined volumetrically by treating the pigment as an iron ore. The remainder of the analysis is practically the same as used for the analysis of black paint pigments. Red lead is another red pigment which is extensively used in the paint industry. It is often adulterated with ferric oxide. As red lead saponifies very quickly with linseed oil it must be used within a few days after being ground, and moreover it is rather difficult to work. To obviate this difficulty of working, many paint manufacturers add some substance such as whiting, which is also less costly. To determine the percentage of litharge in a sample of red lead, boil

the sample for a few minutes with dilute nitric acid (one part acid to three parts water). This will dissolve out the litharge, leaving the lead dioxide. This solution is treated with sulphuric acid and the lead is precipitated as lead sulphate. The lead in the dissolved portion is calculated as lead monoxide. The undissolved portion or lead dioxide, is dissolved in concentrated nitric acid lead dioxide. Red lead consists essentially of 2 parts lead monoxide, and 1 part lead dioxide. From the percentage of lead monoxide and lead dioxide found, it is approximately ascertained if any litharge has been added to the red lead. I have not mentioned two methods of separating pigment and oils which are in extensive use. not settle rapidly and completely when treated with petroleum spirit of ether, the extractor must always be used. Another method is the separation in a centrifugal machine. This form of apparatus is found in many paint laboratories and makes a good separation if the pigment is heavy. The centrifugal machine is not satisfactory when an attempt is made to separate light pigments such as carbon from its oil.

The subject and paper were discussed with interest, and Mr. Snyder was accorded a vote of thanks for his valuable paper.

No further business appearing before the meeting, it was declared adjourned, to meet Thursday evening, January 21, 1904.

GEO. P. MAURY,
Secretary pro tem.

STRUCTURAL SECTION.

A regular meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held at the society's hall, 410 Penn avenue, December 22, 1903. The meeting was called to order at 8.25 P.M. by the Secretary, Willis Whited, 42 members and visitors being present, and on motion George T. Barnsley was elected temporary chairman. The regular Chairman, Mr. J. K. Lyons, arrived almost immediately and took the chair.

Minutes of the previous meeting were read and approved.

On motion the chairman appointed a committee of three to nominate officers for the ensuing year, as follows: Samuel Diescher, Chairman, Charles Worthington, George T. Barnsley.

The speaker of the evening, Mr. E. K. Morse, addressed the section on "Railroad Bridge Construction." The discussion following the address was participated in by J. K. Lyons, W. G. Wilkins, Samuel Diescher, Emil Swensson, and others.

On motion, Section adjourned at 10.20 P.M.

GEO. H. RANDALL,
Secretary pro tem.

[Paper read before the Mechanical Section at their December meeting.]

PUMPS AND PUMPING MACHINERY.

BY G. A. F. AHLBERG.

A pump is not a very intricate machine in itself, and its parts are comparatively few, but its action, or want of it, sometimes makes it seem most mysterious. Although a pump in itself is so simple, there are not many pumps in the market that may be said to be perfect, or anything like approaching perfection; they are spoiled, either on account of cheapness in manufacture, or perhaps sometimes by the makers' peculiar fancy.

To those who have not considered the question of water dispensation, the remark that pumping machinery stands pre-eminent among the various branches of engineering, a few instances may be given to give illustrated proof: How could our large cities be supplied with water, or our coal obtained, or steel works, blast furnaces or coke works kept in operation, were it not for the pumping plant? or how could our sewage works, chemical works, irrigation and drainage be carried on? When man enters nature's storehouse in search of wealth, he finds water ever ready to dispute his search of supremacy. It may be in a constant stream, varying only with the season, oftentimes waste quantities are stored in crevices of the rocks. Some idea of the quantity of water raised will be given when it is known that often its weight is six to seven times in excess of the mineral raised.

Of the origin and early history in the art of raising water we know nothing, but it must of necessity have been one of the first mechanic arts to engage the attention of man. The Chinese, although in many branches of art claimed to be the pioneer, cannot claim any priority in this special branch, which is peculiar, the more so when we consider their manner of irrigation. A pump is even now a rarity with them.

It does not appear to have been known to the Greeks or Romans. The Egyptian wheel was a common machine in Asia, and in remote corners remains in use yet. Danish missionaries in a village of Siam discovered the immediate offspring of this wheel. It was turned by as ass, and carrying round it not pots, but a band of hay, which being drawn through the water, collected the fluid upon it, and delivered it up through a wooden trunk.

Hero, a mathematician and a natural philosopher of Alexandria, that capital where most of the sciences were born, was the pupil of Ctesibius about 150 B.C. The performances of Hero and Ctesibius are spoken of as curious novelties. The expansion of steam, the slide valve, clack valve, illustrating the application of a metallic piston to a metallic cylinder, and about a hundred other inventions, are described and illustrated by Ctesibius, which at the present time would be classified under the head of mechanical engineering. The clear manner in which they are described leaves no doubt of the advanced knowledge possessed by Hero and Ctesibius of that class of mechanism from which our present steam engine and pump probably date their origin.

Although the pump was invented about 150 B.C., it was not until the beginning of the seventeenth century thit its true principles were understood, it being generally thought to act by means of force called suction, though no attempt to discover the reason why water rose upwards under a piston was made until the time when a pump-maker to a royal duke in Italy complained that the water would not rise higher than thirty-two feet or thereabouts. Galileo was applied to for a solution, but does not seem to have solved the question. His pupil, Torricelli, considered that the atmospheric pressure might be the counterpoise to the thirty-two feet of water when received into vacuum. The experiment was tried in 1643 and the supposition was found correct and confirmed later by Pascal.

From this experiment emanated the discovery of the barometer.

A singular incident happened a man of Seville who undertook to raise water from a well sixty feet deep by a common pump. Instead of making the sucker play within thirty feet of the water, he made the rod so short that it did not reach within fifty feet of it. As a necessary consequence he could not raise any water. Being greatly disappointed he descended the well to examine the pipe, while a person above was employed in working the pump, and at last, in a fit of despair, he dashed his hammer violently against the pipe. By this act a small opening was made in the pipe about ten feet above the water, when the water ascended at the spout. This fact being published in 1776 led to a reinvestigation of the subject, and instead of overthrowing the received doctrine of atmospheric pressure, more fully confirmed it. It was ascertained that the air on entering the pipe became mixed with water, and which therefore instead of being carried up in an unbroken column was raised in disjointetd portions, or in the form of thick rain. The mixture being much lighter than water alone, a longer column of it could be supported by the at mosphere, and by proportioning the air admitted a column of the compound fluid which may be elevated one to two hundred feet.

CLASSIFICATION OF PUMPS.

The pumps may be divided into three classes: I—Lift Pumps; II—Force Pumps; III—Lift and Force Pumps.

A *lift pump* brings the liquid upon the piston, working up and down in a cylinder, to the upper end of which a pipe may be fixed, the upward motion of the piston then raises the water at every successive stroke until it eventually reaches the top of the cylinder or pipe. The height to raise water this way is only limited by the strength of the material and the force available. The atmospheric pressure is employed to raise the water a portion of the height.

A *force pump* brings the liquid beneath the piston, working up and down inside the cylinder, the downward movement or stroke of the piston forcing the fluid up through a pipe.

A *lift and force pump* combines the two mentioned classes

as the name indicates. These three classes may be sub-divided into: Single Acting Pumps, Double Acting Pumps, and still further into: Horizontal Pumps, Vertical Pumps.

If pumps be classified according to their details of construction, we have: Bucket pumps, piston pumps, plunger pumps, bucket and plunger pumps, bucket and piston pumps, piston and plunger pumps (differential plunger), rotary pumps, centrifugal pumps. This classification is not exact or scientific, but a commercial one, and therefore in a direct line of every day use. The increasing sub-division in business enterprises and the growing importance of pumping machinery as a part of the plant, would seem to call for another classification of pumps adapted for special uses, for instance: Acids, alkalis, ammonia, bleacheries, breweries, drainage, marine, mining, oil line and oil refinery, salt water, sewerage, sugar house, etc. To give a list of different uses would occupy more space and time than could be given in this paper.

GENERAL RULES IN DESIGNING PUMPS.

In designing a pump the most prominent feature will be pointed out, and must not be overlooked: All valves and ports should be arranged so as to obviate the possibility of *air pockets* at any part. The air always rises to the highest point. This important feature has often been disregarded, even among the most prominent pump builders to-day. The various sections of the pump should always have, as near as possible, the same area, for the reason that when the area increases or decreases the speed of the water is likewise affected, consequently a shock occurs when currents of water with different speeds meet. All bends should have an easy curve. All passages should be made round, because they create less friction and are stronger. Change of direction in the flow of water should be avoided as much as possible. Sharp corners should always be avoided, except where the current of water is desired to be split, as in centrifugal pumps with suction admission at each side of the casing. The top of suction valve box should never be on top of the pump barrel. The under side

of the delivery valve seats should be level with or above the top of the pump barrel. The clearance space should be made as small as possible, the distance between suction and delivery valves and the plunger or piston, should be as small as possible, otherwise the suction power of the pump will be greatly reduced. Hand-holes and covers, for access to the valves, buckets, pistons and plungers, should always be provided for easy access for repairs and cleaning. Uniformity of metal all through each casting should be considered, to avoid shrinkage cracks. No studs should be used, wherever through bolts can be put in, as much annoyance, loss of time and also a great loss of money is caused by a stud breaking, as the old stud generally must be drilled out before a new one can be put in; bolts are also cheaper. This is most important in mining pumps.

Always make the valve area and water passages large enough consistent with the speed of the pump. The area of clear water way through a set of valves should not be less than 40% of the plunger area, for pumps having a speed of 100 feet per minute; for 150 feet it would require from 60 to 70%, and a piston speed of 200 feet per minute should require a valve area at least equal to the plunger area. A good common practice is to make the valve area such as to give the water a velocity of 250 feet per minute. The lift of the valves should be of such height as to give a full and clear passage for the water to flow through, and as to size of valves, it is better to use a number of small valves than a few large ones, on account of the smaller lift required, as it must be remembered that the water passage not only depends on the area, which increases as the square of the diameter, but also on the circumference which varies in direct proportion to the diameter. The flow of water through the valve seats is depending on the area only, but the escape of the water under the valve into the chamber is depending on the circumference. The size of valves now used most commonly is between 3 and 5 inches in diameter, but some years ago certain pump builders went to such an extreme as to employ valves less than two inches in diameter for water works engines; this of course was bad

judgment and was afterwards corrected. Twenty-five to fifty years ago it was a common practice to use valves 8 to 12 inches in diameter; therefore it may be said the present practice is the happy medium between the other extremes. The ordinary type of valves for ordinary and low service, say up to about 150-pound pressure per square inch, the valve disc is made of vulcanized medium hard india rubber, covered with a bronze plate and having a stem screwed in the center of the valve seat. The stemhead limits the lift of the valve and prevents the valve from drifting sidewise. The springs used should be true cylindrical in preference to conical. For higher pressure very hard and thick india rubber is used, but bronze valves are most common and most serviceable; sometimes the valves are made of steel when the nature of the liquid is such as to prevent the use of bronze. Ball valves are commonly used in deep well and tar pumps and are usually made of bronze or iron and seats in a bronze or iron ring simply by its own weight, its lift is limited by some device on the top. The valve used on the Riedler pump is mechanically operated. Only one valve of this type is used on each inlet and outlet of the pump, and they are mechanically closed just as the direction of motion of the pump piston is reversed. By the use of this valve large water ways are provided, and by its mechanically closing, slip and pound is prevented when the pump reverses. Rotary and centrifugal pumps can be operated without valves of any description, but it is desirable with these pumps as with all others, which are used for water works purposes, to use a check valve on the discharge, so that in case any accident should happen to the machinery, the reservoir, stand pipe, or other device for storing water, will not be emptied through the broken pump into the pumping station. In the case of rotary or centrifugal pumps the check valve is particularly necessary, as when the power ceases to be applied, the pump will discharge the stored water back through the pump and suction pipe into the source of supply.

In a pump not having enough valve area, the lift must be increased excessively, and then the valves will close too late and the pump commences to churn; that is a quantity of water

will pass under the valves to the suction pipe, and when the pressure overtakes the valves in their downward movement, the velocity is so accelerated as to cause the valves to slam against their seats with great noise. Nothing will relieve the noise until the speed of the plunger is reduced.

AIR AND VACUUM CHAMBERS.

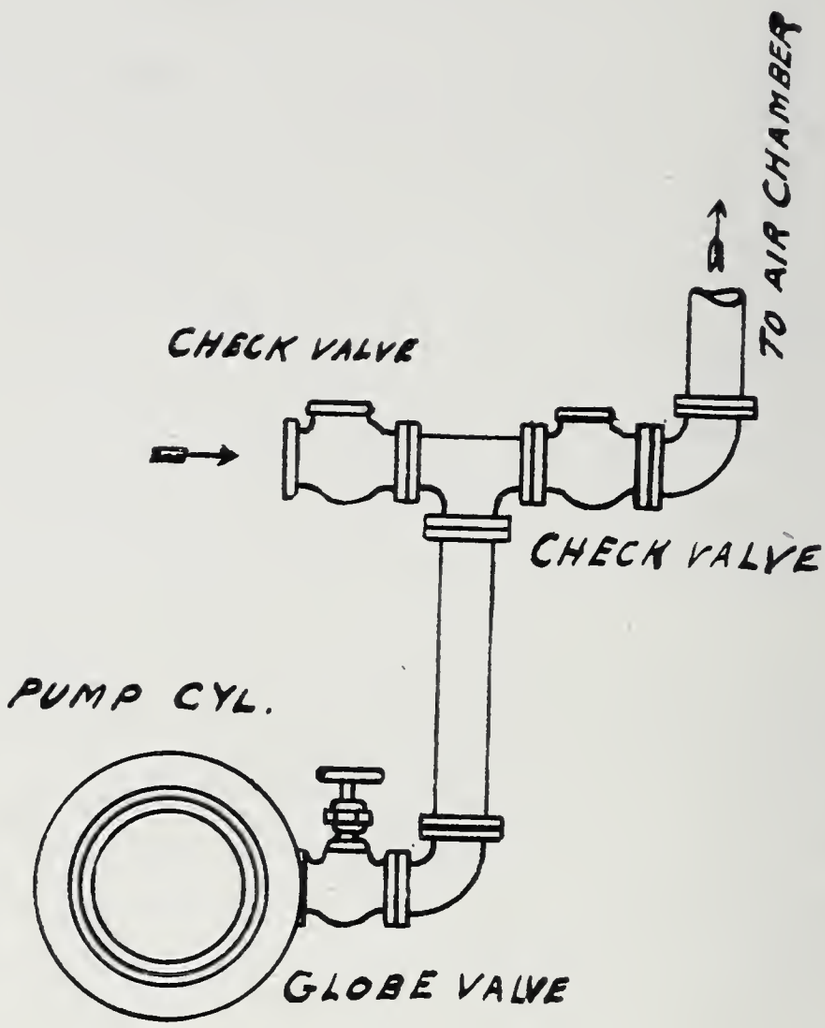
All displacement pumps except the continuous variety, and even those, unless the continuity of the flow is perfect, should be provided with air and vacuum chambers on the discharge and suction pipes, in order to take up the irregularities of flow due to intermittent or irregular action and prevent injurious and sometimes destructive shocks. The size of air chamber depends upon the system of working, the greater the irregularities the larger the chamber should be. Therefore high speed pumps, or a pump forcing water through great lengths of pipe or against a high head, the air chamber should be enlarged, over what would be needed with slow running pumps and low lifts.

For double-acting single pumps the air chamber should be from three to four times the displacement of the pump, providing the speed of the pump is moderate and the pressure under 100 pounds, but for higher speed and pressure it may have to be increased to six or eight times the size. For double acting duplex pumps the air chamber need not be more than from one-half to two-thirds of the size required for single pumps. Triplex pumps under low lifts can get along with an air chamber of capacity equal to a single displacement of the piston.

The air chamber should always be placed on the highest point of the pump and it must be placed above the highest delivery opening of the pump.

For large and medium sized pumping engines, means for supplying air chambers with air should also be provided; for the largest sizes, independent airpumps are very often used, but for small pumps it can readily be accomplished by connecting a small check valve with the pump chamber, so when

the pump inspires, it will draw in a small amount of air with the water; a globe valve outside of the check valve will control the amount of air if desired. Another more effective and still simple device is commonly used, consisting merely of two small check valves, a globe valve, a tee and a few fittings arranged like the sketch. The check valve to the left is placed



to open inwardly, and the other check valve outwardly leading to the air chamber. As it may be readily understood, after the pipe leading to the check valves is filled with water, and when the pump inspires, it will lower the water column in the pipe, and thus create a vacuum; this will cause the check valve to the left to open and fill the empty space with air; on the return stroke of the plunger this air will be forced through the check valve to the right into the air chamber. The globe valve or cock placed next to the pump chamber is to regulate the amount of air required in the air chamber.

The function of a vacuum chamber is entirely reversed to that of an air chamber. An air chamber is placed on a pump to change an intermittent flow to a continuous one, the vacuum chamber serves as a storeroom for a continuous flow to be converted into an intermittent one. When the suction lift is a very small one the suction pipe short, a vacuum chamber is not absolutely necessary for proper running of the pump, but when the suction lift is high and the supply pipe long, a vacuum chamber must be used to take up the inertia of the water column, which will prevent the water hammer and other evil influences. The vacuum chamber should be placed as near the pump as possible. Ordinarily the size should not need to be more than about half the capacity of the air chamber used, but it is preferable to make it long and small diameter.

SUCTION AND DELIVERY PIPES.

The suction pipe should be as short and direct as possible, and everything which would tend to restrain the free flow of water should be carefully guarded against. It should be large enough and of one diaemter from end to end; the velocity of flow should not exceed 200 feet per minute. A slower movement of the water is desirable for the reason that the resistance is reduced and cramping or enlarging the pipe at places will interfere with that uniform rate of flow so essential to proper filling of the pump. The suction pipe must be air tight and should have a continuous rise from the water level to the pump; any irregularity in laying would create air pockets. No more angles and bends should be used than absolutely necessary; should the conditions compel the use of many bends, the diameter of the pipe should be correspondingly increased.

Long suction pipe or high lift require a foot valve. The function of a foot valve is to hold the water in the pipe in case of temporary shutdown of the pump and also for "priming." Suction consists in creating a more or less perfect vacuum in the suction chambers and suction pipe and filling the same with water at atmospheric pressure. Before a pump will

work properly it must be able to create such a vacuum or to "prime" itself. The priming of a pump when there is no water requires either filling of the pump from some other source and a consequent expulsion of the air, or that the empty pump shall act as an air pump and thus remove the air. When there is water to be had from the delivery line, a charging pipe should be connected from said line to suction pipe for priming purposes, to fill the suction pipe and pump with water. A relief valve should be placed somewhere above the discharge valves. This relief valve should be opened when priming a pump in order to allow the air to escape.

The size of the delivery pipes required is nothing else but a problem of friction, and if the line is long, the first cost and the coal bills will have a great deal to do with determining the size. Pumps manufactured for the trade have usually the delivery opening of such a size as to give the water a velocity of 300 to 400 feet per minute.

LOCATION OF PUMPING MACHINERY, ETC.

The conditions under which the water supply must be obtained will to a large extent control the type of pump to be used. It is always desirable to place the water end of the machinery as near the water as possible, while the power end must usually be placed above high water, or if placed below water, it must be placed in a water-tight shaft or compartment. The ordinary horizontal type or reciprocating pumping machinery should seldom be placed more than 18 feet above the lowest water it is called to handle. A suction lift of 24 or 26 feet is however sometimes possible. Where the distance from pump to water surface is greater than the maximum, and especially where large volumes of water are to be handled, such lift becomes hazardous or impossible, and other types of pumps must be used for other methods of locating the machinery employed. The most obvious methods of reaching water when it is below suction distance is to sink the pump to such depth below the surface as to bring it within easy suction distance of the water. When the distance is not too great and

where the conditions are favorable this can readily be done, and this method has frequently been employed. The water ends of pumps demand but comparatively little atention. The flow of the water lubricates most of the parts to a considerable extent, and such as are not in this way sufficiently lubricated can be easily cared for by attention at ocasional intervale. The motor end of the pump, however, is usually more complicated and necessarily requires more particular and constant attention. When, therefore, the depth at which the water is obtained is considerable, it is often desirable to rearrange the design of the pumping machinery, placing the water end with easy suction reach of the supply, and the motor end within easy access from the surface or high water mark, and also near the source of power. This has given rise to various types of vertical pumping machinery.

In some cases where the water is raised from deep wells from a depth of 150 feet or more below the surface, electrical transmission is used, the current supplied from a central generator, the water being raised by separate pumps and forced into the reservoir near the surface, from which it is taken by a surface pump and pumped into the mains and stand-pipes. This is done where shaft and tunnel work is expensive and where it becomes desirable to install small isolated plants on each well, which may be operated singly or together as the water required demands. Separate stea mpumps may be applied to such wells, but usually such pumps are far from economical, and particularly in cases of this kind.

Pneumatic and hydraulic transmissions are also sometimes used. As an example how hydraulic transmission is used with good efficiency; a centrifugal pump is put in each well operated by impulse water wheels. The water which operates these wheels is taken from the mains, supplied by a high duty engine. This water together with the water pumped by the centrifugal pumps is returned to the main supply well.

DIFFERENT TYPES OF PUMPS AND PUMPING MACHINERY.

In a large and important class of pumping machinery the steam and water cylinders are placed in the same machine

in a compact shape, such pumps are called *steam pumps*. Numerous varieties of this class of pumps are in use.

From the methods of application of steam this class of pumps is divided into *high pressure* steam pumps, which include all those in which steam is used at its initial pressure for a full length of stroke in the cylinder and not again used, and *compound* steam pumps, in which the steam is used expansively in two or more cylinders. The arrangement and design give rise to other divisions. In the direct acting pump the steam piston is connected by means of a piston rod with the pump piston or plunger, the piston rod being common to both steam piston and water plunger. The only method of using steam in this form of pump is to exhaust it from the high pressure cylinder directly into the low pressure cylinder and use it in both cylinders for the full length of stroke, and without the use of cut-offs. The gain in compounding such a pump over a high pressure steam pump is from 20% to 30%, depending upon the initial steam pressure and ratio of expansion. The initial steam pressure should not in this be less than 70 pounds.

The *duplex steam pump,* so familiar to everybody for its ideal simplicity, with its efficient valve motion, to which it owes its complete exemption from noise or concussive action, is due to the late Henry R. Worthington. It consists of two steam pumps side by side, with the valve motion so designed that the movement of the steam piston of each pump shall have the controlling movement of the steam valve of its opposite pump, the effect of which is to allow one piston to proceed to the end of its stroke and gradually come to a state of rest. During the latter part of this movement the opposite piston then moves forward in its stroke, and also comes to a state of rest, but in its movement forward and before reaching the end of its stroke, the steam valve controlling the first piston is reversed, and in consequence the first piston returns to its original position, and in nearing the end of it stroke it, in a similar manner, reverses the steam valve, controlling the second piston. These movements are both uniform and continuous.

The time allowed at the end of each stroke before the piston takes up its return motion is sufficient to permit the water valves to seat quietly and to allow the incoming supply to completely fill the water cylinder.

To attain the best economy possible with greater rates of expansion, and still obtain the compactness of this type of pump, various types of compensators have been introduced. The Worthington device is perhaps the best known type. In this machine the energy of the steam at the beginning of the stroke not only overcomes the resistance of the water pumped, but also forces hydraulic plungers, moving in trunions, against a fixed pressure stored in an accumulator. When the center of the stroke is reached this stored energy is gradually returned to the pump after the steam is cut off and when it is expanding in the cylinder. A decided increase in the economy of operation results.

Another type of compensator is the Heisler. In this form of compensator the cylinder of one side at full steam pressure transmits a portion of its force to aid the other side, which is working expansively.

The greatest economy in pumping machinery has been developed by what is known as the crank and fly wheel type, of which the Allis type is probably the most popular at the present time for large water works engines. These engines can be seen at Brilliant Pumping Station. But the Allis-Chalmers Company are not the only builders of this type, alhtough Mr. Edwin Reynolds must be given credit for the original design, as applied to pumps.

HYDRAULIC OR HIGH PRESSURE PUMPS.

The transmission of power by means of water under high pressure is now generally employed in handling Bessemer converters, cranes, charging apparatus and other machines in the steel works, also in ship building, boiler making and other kindred establishments, in riveting, shearing, punching, bending and flanging machines and for numerous other purposes.

The duplex steam pump is the one in general use for

this class of work. Geared power pumps or pumps driven by independent steam engines are seldom met with. Attempts have been made to introduce crank and fly wheel pumps for this class of work, on account of economy of fuel, but to the writer's knowledge never met with any particular success. The reason for this is very obvious when the nature of operation is taken into account, and particularly so in steel works. The hydraulic machinery is the most expensive and the hardest worked part of the plant, and the constancy and steadiness of the pumping power is the most vital feature of the whole machinery. Any delay or serious fluctuation in its operation in handling fluid masses of iron and steel is fatal to the commercial success. The strain on the pump is constant, but the velocity momentarily and suddenly varies by the demand for water from a low to the highest speed, and sometimes the pump may stop momentarily and then be suddenly brought into service. To meet successfully with these conditions a crank and fly wheel pump could hardly be thought of.

Compound steam pumps are not recommended for pressure pumps where the service is very irregular, that is, where a pump works with great violence for a few minutes and then comes to a state of rest. If the action of the pump could be made continuous over long intervals of time, say several hours, then compounding is recommended, providing the initial steam pressure is not less than 70 pounds. In many cases however the pump could be made to work more regular, provided it is made large enough for the purpose, and if a large enough accumulator is furnished.

In designing the water end of these pumps extra precaution should be taken in selecting the proper metal to suit conditions, also, first and last the design itself. The water end should be made in several parts, so in case of breakage of any part it can be easily replaced with little cost or delay. In the general remarks made on designing pumps in the first part of this paper, it is of most importance to be particular in having all parts of the pump end made round with absolutely no air pockets. And do not be stingy with metal. Shocks will be transmitted from machinery operated by the

pump sometimes amounting to several times the ordinary working pressure. Sometimes this will be caused by a descending accumulator running at high velocity. The sudden arrest at the botom of its fall causes a blow, and water being practically incompressible, the shock is transmitted throughout the whole system including the pump. For these reasons the ordinary factor of safety as ordinarily used, for figuring thicknesses of metal, is not at all sufficient, especially if cast iron is used. Cast iron has a tendency to split open at the center of juncture of two or more pieces, and especially if these pieces are of unequal thickness, the common defect being a drawing away of the outer skin of iron from the center and formning a cavity within.

A high pressure pump should have a longer stroke than that ordinarily given to trade pumps, as the wear of a pump depends on the number of reversals of motion made in a given time, their durability is proprotionally increased by this feature.

The water end can be made of cast iron, having a tensile strength of 25,000 pounds to the square inch, providing the plunger is not more than 7 to 8 inches in diameter and the pressure not over 500 pounds. If the plunger is more than 7 or 8 inches in diameter or the pressure more than 500 pounds and not over 1,000 pounds, good air furnace cast iron, having a tensile strength of 40,000 pounds per square inch, could be used, but the writer would prefer open hearth steel castings, not because the latter is so much stronger, but the nature of it is more like wrought iron, with less chance to rupture. For larger pumps or higher pressure steel castings should be used exclusively.

A few years ago it was almost impossible to get satisfactory castings from the steel foundries in this country, the casting had a terribly rough looking appearance; they were full of blow-holes and almost impossible to machine; but now good steel castings can be had that will answer all purposes.

For small pumps, with plungers not much over 3 inches in diameter, phosphor-bronze has been used with good satisfaction for pressures as high as 7,000 to 8,000 pounds to the

square inch, but phosphor-bronze is porous, and the inside of the castings must be thoroughly coated with parafine, shellac or something kindred, before using.

The valves and seats are invariably made of phosphor-bronze or hard gun metal; a number of small valves with low lifts should be used.

MINING PUMPS.

A great deal could be said about mining pumps, but the writer will only give a few important features at this time.

The service of a mine pump is generally rough, severe and continuous, and very often it has to perform a high duty, being down in the mine and pumping at a high elevation. There are a few cases in this country where the engines are on the surface, but in most cases the pump with the motive power is placed under ground. Great care must be exercised, both in the selection and adaptation of the material used for the construction, as the water to be pumped is often of a kind that will attack and quickly destroy a material not judiciously selected. The location of the mine is usually remote from supplies and necessities for renewals or repairs, and unless they can be made by unskilled labor and with little delay, may be attended with serious consequences.

All parts exposed to pressure should be subdivided as much as possible, and should be properly proportioned as to strength. The valve mechanism should be made as simple as possible, with the least possible chance to get out of order. Outside packed plungers are to be preferred, as dirty or gritty water is the common thing in a mine, which will cut out the cylinder or lining very fast. When the water is full of acids as is invariably the case in the Pittsburgh district, phosphor-bronze plungers and tobin-bronze piston rods are recommended, and in some extreme cases the entire water end must be made of phosphor-bronze.

The singular feature of interest is that, although acid water does not attack bronze, it at times corrodes the iron around the machined surface where a bronze valve-seat or

bronze liner is inserted. The writer believes this is due to a galvano-chemical process taking place between the two metals, the tendency is to loosen the valve seat or liner as well as corroding such other portions as have been machined. The acid does not readily corrode the rough part sof the casting.

Pumps driven by electric motors placed in water-tight casings have been in use for some time and appear to give good service. The advantage of using electricity instead of steam for motive power in the mine is obvious. The steam pump often requires the transmission of steam through long lines of pipes, involving a large loss of steam by condensation, whereas, electric transmission is effected with but a trifling loss, and, at last but not least, the electric current is far more efficient than a steam pump; but on the other hand, the steam pump is by far the simplest machine.

STEAM JACKETS.

The actual value of the steam jacket has always been an open question, some early writers have absolutely condemned it, but it steadily grew in favor with engineers. The writer of this paper does not believe that any saving can be counted on by steam-jacketing a duplex compound pump, and particularly so in the smaller sizes. A liberal covering of some good non-conducting material, mineral wool, hair felt, nonpariel cork, is good for that purpose. This does not exactly take the place of the steam jacket, but it does to a very great extent prevent radiation from the steam cylinders, and if we count up the additional cost of a pump with jacketed cylinders plus the cost of steam required to supply the jackets, it will, in the writer's experience, not be in favor of the jacketing.

For high grade engines, using steam expansively, some saving may be effected, but nothing like 20% to 30%, as some engine builders a few years ago claimed for the steam jacket.

Some years ago "Professor Denton" made a thorough and exhaustive test to determine the value of this. The pump was of the high duty Corliss type, installed at Pawtucket Water

Works. The experiment was conducted along the lines of every-day usage and service, and has a special value for that reason. The conclusions reached by him form a very elaborate and convincing paper published by the American Society of Mechanical Engineers, and the final conclusions are as follows:

1st. That the averages of results of indicator cards, taken in the most careful manner with the best modern indicators, show a possible saving from the use of the jackets amounting to from 0.13 to 0.35 pounds of steam per hour per horse-power, but that these amounts are within the limit of error to which the determination of indicated horse-power and cut-offs are subjected, so that

2d. The most that can be claimed for the jacket is that it probably caused no loss, and may possibly cause a saving not exceeding 3% of the total steam consumption.

DUTY AND EFFICIENCY OF PUMPING MACHINERY.

Duty may be expressed in almost any units, but in pumping it usually represents the ratio of foot pounds of work done to a fixed weight of coal, or steam, or to a fixed number of heat units used.

The terms almost exclusively used to express duty of pumping engines are foot pounds duty per 100 pounds coal, per 1,000 pounds of steam, or per 1,000,000 heat units. It must be understood that the duties expressed in the above units are not necessarily equivalent, but vary largely in actual value. If the coal used evaporates 10.35 of water from, and at 212° F. per pound of coal, the heat units delivered to the engine will be exactly 1,000,000 per 100 pounds coal burned.

Duty based on coal is very indefinite, for coal varies largely in its potential energy or calorific value. When coal is considered, the plant efficiency must also be included. This may include boilers, steam pipe, feed pump, heater, etc., which necessarily have not any relation to the individual efficiency of the pump itself. Duty based on coal should therefore only

be used where the entire plant is considered and when the class of coal is specified. Duty based on steam is more specific, but hardly sufficiently so. Both theory and practice show that, with suitable conditions, steam at 150 pounds pressure has greater value than steam at 90 pounds pressure. The entrained water from the boiler and the condensation in the steam pipe also modifies the results. When duty is based on the weight of steam used, the term dry steam and a specified pressure should also be included.

The duty of a pumping engine may be calculated from the formula:

$$\text{DUTY} = \frac{\text{weight of water pumped x head x duty unit}}{\text{amount of energy used.}}$$

The "duty unit" is 100 for coal, 1,000 for steam, and 1,000,000 for heat units. The "amount of energy used" is the total weight of coal or steam or the number of heat units used.

DUTY AND EFFICIENCY OF PUMPING MACHINERY.

Class—		Duty Per 1000 lbs. of Steam.	Pounds Steam Per I. H. P. Per Hr.	Theoretical Efficiency Per Cent.
High Duty Engine	max.	160	12.3	20.6
	min.	100	19.8	12.9
Pumping Engines	max.	100	19.8	12.9
	min.	75	26.4	9.8
Large well designed Steam Pump.	max.	40	49.5	5.2
	min.	20	99.0	2.6
Ordinary designed Steam Pump.	max.	20	99.0	2.6
	min.	10	198.0	1.3
Direct Acting Deep Well Pumps.	max.	6	330.0	.77
	min.	2	990.0	.26
Vacuum Pumps	max.	8	247.5	1.04
	min.	2	990.0	.26
Jet Pumps	max.	4	495.0	.52
	min.	1	1980.0	.13

These results may be considered fair average results of well designed plants. Results much higher may be obtained under ideal conditions, and much poorer results are only too common in actual practice.

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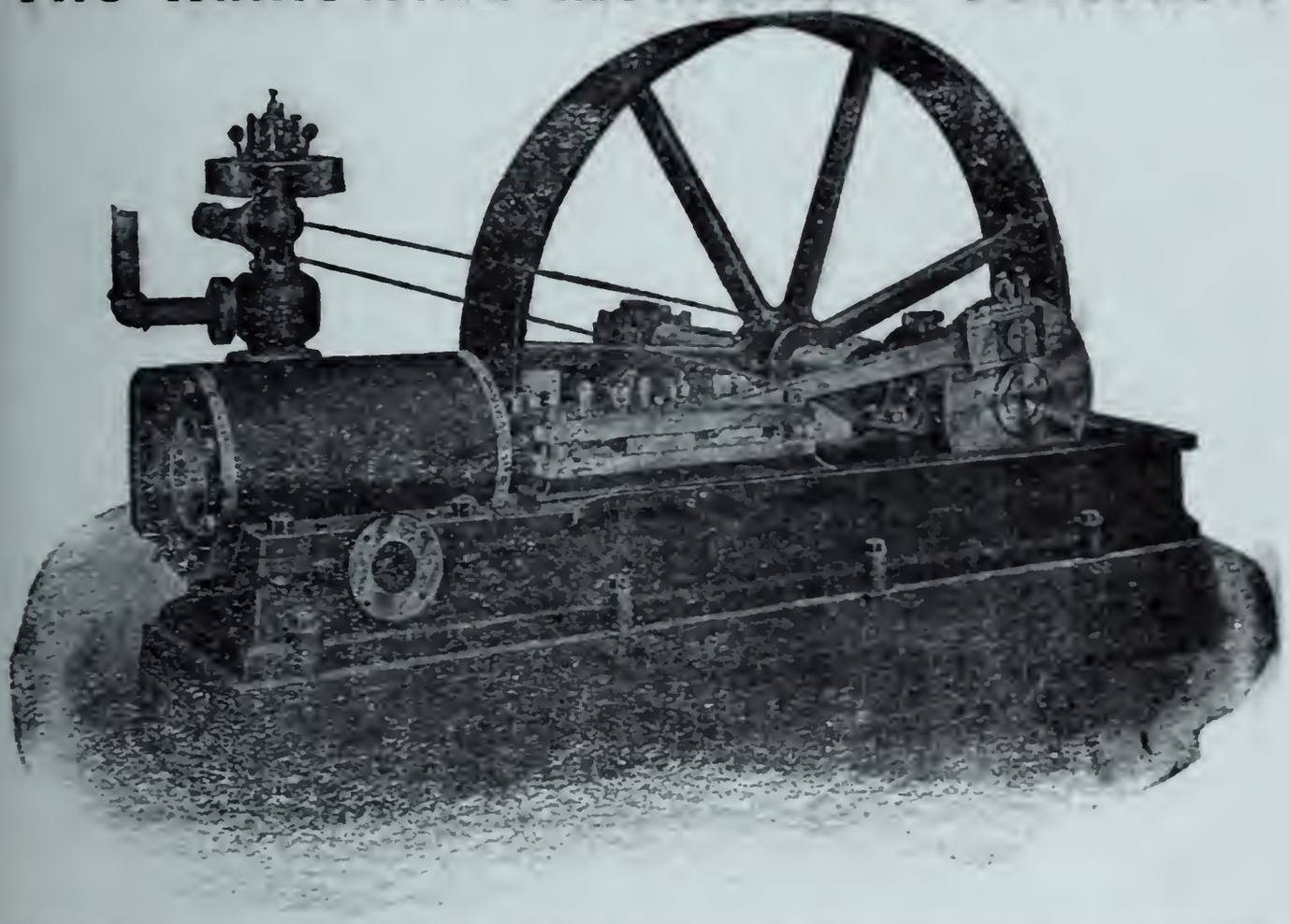
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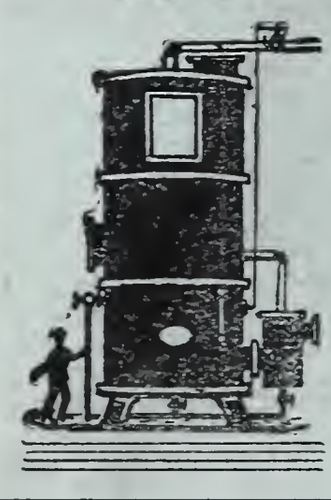
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